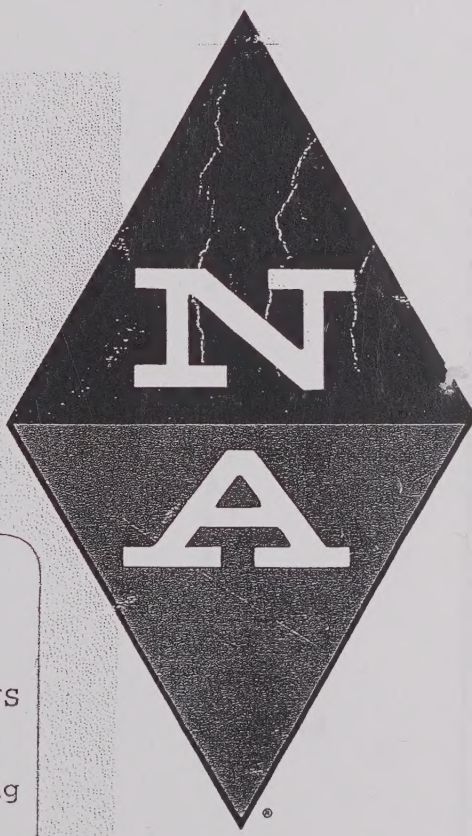
P R E L I M I N A R Y

OPERATING AND INSTRUCTION MANUAL

VM-214C S-1078

PHASE ANGLE VOLTMETER



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NOTE: This is a PRELIMINARY edition.
We ask your help in the following:

1. FILL OUT THE ENCLOSED WARRANTY CARD.
2. WRITE US WITH YOUR COMMENTS AND SUGGESTIONS ON THE FORMAT AND CONTENTS OF THIS MANUAL.

The final manual is being prepared for printing and will be sent to you by April 15, 1966.

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SECTION I

GENERAL DESCRIPTION

The Model 214 Phase Angle Voltmeter is a completely transistorized modularized instrument which combines the ability to measure both phase angle and magnitude of complex AC signals and vector components with respect to a reference voltage. Designed to operate phase sensitively within a frequency range of 30Hz to 20KHz, it utilizes passive phase shifter circuits to assure long-term stability and high accuracy over the spectrum. As a TOTAL voltmeter, the Model 214 is capable of measuring signals within a frequency range of 10Hz to 100KHz. The Model 214C (below) has its frequency response limited to that of the particular isolation transformer in the circuit (see Transformer Spec. Page 1.10 and Isolation Transformers, Page 3.20).

This instrument is characterized by its capability to operate at four separate phase-sensitive frequencies. These frequencies may be changed simply by replacing the frequency determining plug-in modules, consisting of a pair of matched harmonic rejection filters and a plug-in frequency module. The

instrument can be supplied with 1, 2, 3, or 4 sets of plug-in modules. Any unused channel may be left open for field addition if required. Additional or replacement kits of plug-in modules are available and may be added at any time in the future. Panel decals designating frequency are supplied as part of the additional kit.

Front panel controls permit instantaneous selection of range, function, and frequency.

As a phase-sensitive null meter, the Model 214's 2uv nulling sensitivity permits high resolution ratiometric measurements. This allows measurements of low-level voltages of the reference frequency in the presence of noise, hum, and other spurious signals. As a phase meter, angles are read on a high resolution, parallax-free scale calibrated in 0.5^{o} increments.

The Model 214 is available in three basic configurations:

MODEL 214A - No Signal or reference isolation:

The 214A will perform all the basic functions for which the instrument has been designed, except that it does not contain any means for isolating the reference or signals inputs.

MODEL 214B - Reference Isolation Only:

The 214B is identical to the 214A with the exception of the added reference isolation transformer. The instrument is factory wired to accept the plug-in reference isolation transformer. TM40.

MODEL 214C - Both Reference and Signal Isolation:

The 214C differs from the 214B not only by the addition of signal isolation, but it also includes a front panel switch for switching the transformer in or out of the signal input circuit. It also includes a special attenuator which is used to limit the voltage applied to the transformer at low frequencies. In order to prevent damage to the transformer, in the event of inadvertent application of excessive voltage, a fuse is provided on the front panel.

Signal isolation is accomplished in the 214C by means of two separate transformers, each designed for specific frequency bands (see Specifications, Page 1.10).

NOTE: The provisions for all three transformers require factory wiring. The 214 cannot be modified in the field to convert from one version to another.

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APPLICATIONS

A. Phase sensitive null indicator.

B. Measures separately the In-Phase and Quadrature components of an AC signal.

C. Measures phase shift in any AC system.

D. Sensitive AC electronic voltmeter.

E. Testing of servos, computers, synchros, resolvers, inductosyns.

F. Precise AC ratiometry.

G. Phasing of servo motors, chopper amplifier, magnetic amplifiers.

H. Measuring both torque and non-torque producing signals in servo amplifiers.

I. Align carrier amplifier and notch networks.

J. Impedance meter.

K. Power factor meter.

L. Measuring response of vibrational system.

Detailed descriptions of these applications are shown in the Application Notes appended hereto.

MODEL 214A, 214B, 214C

PHASE ANGLE VOLTMETER

GENERAL SPECIFICATION

The following specification applies to all North Atlantic 214A, 214B, 214C Phase Angle Voltmeters. Where a special modification or variation is involved, the governing specification will either be a separate specification control document, the buyer's purchase order, or a supplement contained in this manual. Specifications for special instruments are identified by the specification "S" number appearing on the instrument nameplate.

In addition, the original frequencies of operation as installed at the factory will be identified on this same nameplate. Since these frequencies may be changed in the field, it is necessary to specify all desired frequencies of operation as well as the "S" number when purchasing new instruments.

Voltage Range (Full Scale Output):	300uv to 300V in 13 ranges.
Range Vernier:	Adjustable from 0.3 full scale to full scale (10 x overload is maintained at all settings of the vernier).

Frequency Range:

Total Voltage - 10Hz to 100KHz (Direct) (See Page 1.10 for Trans.)

Phase Sensitive - 1, 2, 3, or 4 frequencies from 30Hz to 20KHz (frequency may be varied ± 5%).

Accuracy:

Voltage:
Total - ±2% of full scale, 10Hz to 100KHz (Direct).

Fund: ±2%, 30Hz to 20Hz.

Phase: ±1° as read on the Phase. Dial, E cos θ ± 3% of full scale angle.

Calibration:

Voltage - Zero center, low stiction meter calibrated 3-0-3 and 10-0-10 scales.

Phase Dial - Continuously calibrated from -6° to +96° over four quadrants 0°, 90°, 180°, 270°.

Resolution - 0.1°, at ends of quadrant, to 0.2°, around 45°.

Signal Input Impedance:

Model A - 10 megohms, shunted by 65uuf, nominal.

Model B - 10 megohms, shunted by 65uuf, nominal.

Model C - 10 megohms, shunted by 75uuf, nominal (Direct Mode)
TM41 = 500K @ 400Hz, (Trans. Mode) 300uv to 10V Range.
TM42 = 250K @ 2.5KHz (Trans. Mode) 300uv to 10V Range.

Reference Input Impedance:	Model A - 10 megohms, shunted by 65uuf nominal, for both high and low positions. Models B and C - 100K ohms, shunted by 120uuf, nominal.
Reference Input Voltage:	Model A - 50mv to 150mv max. Models B and C - 1V to 150V max.
Input DC Voltage Level:	Models A and B - 400V, max. Model C - (with no external blocking capacitor) (See Section II, Page 2.10)
Overload:	10 x overload capability. Overload light will ignite at approximately 11 x full scale setting.
Noise:	Less than 15uv, Total and Fund Modes.
Nulling Sensitivity:	Less than 2uv, Phase Sensitive Modes.
Harmonic Rejection:	Fundamental - See Diagram, Figure 3.4 (Page 3.19). Phase Sensitive - 2nd harmonic - 55DB 3rd harmonic - 40DB to 70DB. depending on frequency of operation (See Figure 3.4, Page 3.19). All others - 60DB

Non-Coherent Signal Rejection:	For frequencies removed from signal frequency by approximately 5Hz or more (effective pass band of meter movement) response is essentially nil for levels up to 10 x the value of the full scale in use. Appropriate filters can increase the allowable level of the non-coherent signal to 300 times the value of the full scale in use on the most sensitive scales.
Power:	115V/230V ± 10% - 50-440Hz at 40W.
Fuse:	For 115V Power: .5A, Type 3AG For 230V Power: .25A, Type 3AG Signal Transformer - .05ma, Type 3AG (resistance not to exceed 30Ω).

Accessory Plug-In Modules:

Model TM40-Reference Isolation Transformer:
- Frequency Range - 30Hz to 20Hz
- Voltage Range - 1V to 200V when used in 214B or 214C

Model TM41-Signal Isolation Transformer (Low Frequency)
- Frequency Range - 30Hz to 2.5Hz
- Voltage Range - to 300V max. when used in 214C.

Model TM42-Signal Isolation Transformer (High Frequency)
- Frequency Range - 2.5Hz to 20KHz
- Voltage Range - to 300V max. when used in 214C.

MECHANICAL SPECIFICATIONS

Size:	Panel is 5-1/4"H x 19"W Depth behind panel is 12"
Weight:	20 to 25 lbs. depending on number of modules included.
Mounting:	Rack or bench mounted.
Front Panel Paint:	Gray #26440 per Fed. Std. 595
Front Panel Marking:	Black #37038 per Fed. Std. 595
Line Cord:	6'long. std.
Front Panel Input:	Inputs are standard, 5-way binding posts, spaced on 3/4" centers. Ground terminals are colored black and marked Ground.

SECTION II

OPERATING INSTRUCTIONS

Removal From Package

This instrument has been thoroughly tested, inspected, and evaluated at the factory prior to shipment. Particular care has been taken in the design of the special wrapping and packaging material used in the container to ensure that no damage result from the typical handling encountered during shipment. However, upon removal from package, the instrument should be externally inspected for any obvious damage. Should such be observed, refer to the Warranty Policy previously presented.

Prior to making any connection, check the meter to see that it reads 0. If it does not, reset the meter to read 0 by means of the Zero Adjust screw which may be reached through the front panel. This adjustment must be done with the power off and with the instrument in a horizontal or near horizontal position.

Power Line Voltage and Cable

The Model 214 is normally wired for 115V operation. If it is desired to operate the instrument from 230V source, refer to the transformer conversion illustration of Figure 3.2 for the correct procedure.

- NOTE: Be sure to use the proper fuses for the desired operating voltage. 115V source will be .5 amp, Type 3AG, fuse, and 230V source will be .25 amp, Type 3AG, fuse.

All electrical circuit and power grounds are floating with respect to the chassis. The instrument is supplied with a three prong power plug. The round pin is wired to the chassis. Common grounding of power, chassis, and circuit ground is accomplished by means of a link on the signal input terminals. The circuit ground must be connected to chassis ground either at the input terminals or remotely. Dependent upon specific application, it may be more desirable to wire the chassis such that it is not connected directly to house ground. In those cases, extreme caution must be taken to avoid any personal injuries due to the resultant shock hazard. As

a general rule, every effort must be made to ensure that the chassis is wired to a house ground at all times.

Controls, Displays, Inputs

Prior to attempting to operate this instrument, it is advisable that the user familiarize himself with every control, display, and input connection as described below.

ON-OFF Switch

The Power Switch for the Model 214 is located on the Frequency Switch. The instrument is turned on by moving the outer knob to any of the frequencies designated on the front panel. When the switch is placed in any of these positions, the meter face will be illuminated.

The Phase-sensitive frequency to be measured is selected by setting this same outer knob to the frequency desired. This selects the proper frequency and phase-sensitive components.

Reference High-Low Selector

The Reference High-Low Selector switch is located directly above the Frequency Selector switch and is a slide switch which inserts an attenuator in the HIGH position to allow the use of high level reference inputs.

Reference Vernier

The Reference Vernier Control is the center knob located concentrically with the Frequency Switch and is used for adjusting the reference level to read half scale (red line) on the meter.

Function Selector

The Function Switch selects the desired mode of operation for the instrument. In the four Phase Angle Voltmeter positions, the instrument is connected so that it may read a voltage E cos θ where θ is the angle by which the signal vector leads the reference vector. Any of the four quadrants may be selected over which the calibrated phase

shifter will operate. Thus, the total angle by which the reference vector shifted in degrees will be either 0^{o}, 90^{o}, 180^{o}, or 270^{o} plus the reading of the Phase Dial.

In the VM Position, the instrument functions as a standard voltmeter and will read all voltages over a frequency range of 10Hz to 100KHz. In the Fundamental Mode, the instrument will read the total vector of the fundamental component of the input signal, (see Figure 3.4 for filter characteristics).

The Function Selector must be positioned in the Ref. Adj. position in order to make the proper reference adjustment. Note that in this position, the light marked Ref. Adj. will be turned on.

Range Selector

The Range Selector is a rotary switch which selects the proper attenuators for the desired full scale voltage by means of its outer knob. The center concentric knob is a range vernier control which permits the adjustment for

full scale sensitivity, as desired for deviation measurements. This control will turn on the VARIABLE light on the front panel which indicates an uncalibrated condition exists. The control must be in the extreme clockwise position for calibrated operation.

Phase Dial

The Phase Dial is calibrated to read the degrees of phase shift introduced by the calibrated phase shifter networks within theparticular quadrant selected by the Function Selector. TheDial is calibrated from -6^{o} to $+96^{o}$ in 0.5^{o} graduations. Mechanical positioning of this Dial on its shaft is critical and for this reason, should it be necessary to repair or replace, the procedure under Phase Dial Alignment should be followed.

Overload Indicator

The lamp marked OVERLOAD is turned on whenever a prescribed signal level is exceeded. This indication warns of

impending amplifier overload and the attendant inaccuracies which will occur when large saturating signals are present. The overload indicator is factory set to turn on at 11x full scale. (The instrument will function within its specified accuracy up to and including a 10 x overload).

Voltmeter

The meter is a zero center low stiction microammeter calibrated to read the RMS value of a sinewave. For all VTVM readings, the pointer deflects to the right. For Phase Angle measurements, the meter deflection may be to the left or right. It has a calibrated zero center 3-0-3 and 10-0-10 with mirror backing for more precise readability.

CAUTION: By its nature, the instrument is required to handle inputs considerably in excess of its full scale reading. Although an extreme overload capability has been designed in, discretion should be used to avoid application

of signals in a manner which will drive the needle hard against the stops. Therefore, always approach a measurement from the least sensitive position and return to this position before making circuit adjustment. This approach will avoid any damage, which may occur to the meter.

Input Terminals

In the 214A, five terminals are provided at the front panel for connection to external test circuits. Terminals for both the signal and reference inputs are colored black for circuit ground and colored red for the high side of the input.

In the 214B, the reference input terminals are colored red and black which indicates polarity with respect to the signal terminals (i.e., red is in-phase with red, and black is in-phase with black). See below for 214C.

These posts are on standard 3/4" spacing and will accommodate

banana plugs, wire, or alligator clips.

CAUTION: Maximum signal input must not exceed 300V RMS and maximum reference input must not exceed 200V. Higher voltages will break down the input capacitors in the instrument. (See Specifications, Section I).

A third terminal is provided at the signal input for connecting circuit ground to chassis ground. A link is provided between the metal terminal and the ground (black) terminal of the signal input to allow maximum flexibility of connections. The link is provided to permit grounding at the input terminals or to a remote point in measuring setup. Great care should be given to grounding methods used to avoid ground loops and stray fields. The instrument will not read properly if the input is not grounded.

The Following Applies to Model 214C Instruments Only:

The Model 214C instruments are characterized by the inclusion of a Signal Isolation Transformer with facility for switching the transformer in or out of the circuit.

The items listed here exist on the Model 214C front panel only.

Input Selector Switch - The Input Selector Switch is a slide switch which removes the input transformer from the input circuit in the DIRECT Position allowing for single ended direct coupled inputs. In the TRANSFORMER Position, floated inputs or differential inputs, as well as single ended isolated inputs, may be fed into the Signal Channel.

NOTE: In order to provided as wide a frequency range as possible and avoid any degradation, a blocking capacitor has not been included in the Transformer Mode. In the event that signals containing DC are to be injected in the Transformer Mode, a large blocking capacitor should be used externally.

Signal Input Terminals - Four Signal Input Terminals are provided on the front panel of the Model "C" which allow complete flexibility for Direct and Transformer

inputs. It should be noted that the center terminal is common to both Direct and Transformer inputs and is high for Direct inputs and low for Transformer inputs.

The metal binding post as on the Model A and B instruments is chassis ground.

Fuse - A special fuse (.05 milliamps with maximum resistance of 30Ω) is located on the front panel. It is provided as protection for the Signal Input Transformer in the event that voltages in excess of the rating of the transformer or excessive DC currents are inadvertently applied. A spare is also located on the front panel. Note that the voltage rating of the low frequency Signal Isolation Transformer (TM41) is 0.75f (where f is frequency of operation), 300V max. and 0.12f to 300V max. for the high frequency transformer (TM42).

CAUTION: If it is desired to apply a 60Hz high voltage signal, the Frequency Switch should be placed in the low frequency position prior to the application of the voltage, or conversely, the 60Hz high level voltage should be removed before the Frequency Switch is changed to a higher frequency. This is necessary to insure that the alternate or low frequency attenuator is switched into the circuit to provide the attenuation necessary to prevent damage to the transformer.

OPERATION

Plug the instrument into the proper power source. Turn the Frequency Selector to any desired frequency. This will turn the instrument on, lighting the meter face. Allow the instrument to warm up for a short period (3 to 5 minutes) for stable operation.

CAUTION: Before making phase or voltage measurements, review the section on grounding techniques in the Application Notes appended hereto.

To Measure Voltage

Set the Range Selector to the appropriate scale and the Function Selector to the appropriate position. Connect the voltage to be measured to the signal input terminals and read the voltage from either the 0-10 or 0-3 volts scales using the proper scale factor as determined by the Range Selector position.

With the Function Selector in the TOTAL position, the voltmeter operates as a standard electronic voltmeter. This reads the total vector voltage at any frequency including all harmonic effects. With the Function Selector in the FUND position, the Model 214 will read only the fundamental voltage within the range of the filter chosen by the Frequency Selector.

Notice that with no input to the instrument (terminals not shorted), the meter deflects on the low ranges. This condition is normal and represents a true measurement of stray fields capacitively coupled to the input. Shielding the input will reduce this deflection to a minimum level. Measurements made on high impedance circuits require that special attention be paid to capacitive as well as inductive pickup.

Twisted and/or shielded cable will reduce the effect

although the cable capacity could serve to load the source. Care must be taken where possible to insure that ground loops do not exist by virtue of the signal and reference grounds being connected. These loops can result in erroneous readings. (Refer to the Application Notes appended hereto.)

Phase Angle Measurements - With Calibrated Phase Shifter

1. Set the Frequency Selector to the proper frequency of the signal to be measured.
2. Switch the Function Selector to the REF ADJ. Position.
3. Inject the reference signal into the reference terminals and adjust the High-Low Switch and the Reference Level Control to cause the meter to read a value as indicated by the red mark on the meter scale.
4. Switch the Range Selector to a suitable position and inject the the signal to be measured into the proper terminals.
5. Set the Phase Dial to 0^{o}.
6. Switch the Function Selector to a Phase-Sensitive Position which will cause the meter to read to the right.
7. Turn the Degrees Dial to cause the meter to read near maximum. This step is to provide a course deflection of the phase angle.
8. Switch the Function Selector 90^{o}.
9. Turn the Degrees Dial until the meter reads 0.
10. Switch the Range Switch to two ranges more sensitive (e.g., if Step 9 is performed on the 100mv Range, then this should be done on the 10mv Range position).

11. Adjust the Phase Dial more precisely for a null on the meter.

12. Switch the Function Selector to a position (0, 90, 180, 270°) which gives a meter deflection to the right.

13. The phase angle is then the sum of the Function Selector angle plus the Phase Dial angle. This rule eliminates the possibility of ambiguity. In the event the user makes a measurement with a deflection to the left in Step 12, add or subtract 180° from the sum of the quadrant and Phase Dial Angle.

Phase Angle Measurements with In-Phase and Quadrature Components

Accurate measurement of phase angles can also be made using the E cos θ or E sin θ characteristic. Voltage measurements are made from the in-phase or quadrature component of the fundamental signal (Fundamental position). The quotient will then be the cosine, or sine, or tangent of the unknown phase angle. Trigonometric tables, slide rule, or graphs included in the appended Application Notes are suitable for converting to degrees. The accuracy achievable using this technique depends upon the procedure, and for that reason it is suggested the Application Notes be reviewed before using this method.

1. With reference level set, place Function Selector in the 0^{o} position. Set the Phase Dial to 0^{o}.
2. The meter now reads the in-phase component of a signal. This is also E cos θ where θ is the angle between the reference and signal.
3. Switch the Function Selector 90^{o}. The meter now reads the quadrature component or E sin θ. In general, one of these components is usually much smaller than the other and for greater accuracy, it is convenient to change the range of the instrument. This can be done until the overload lamp lights thereby warning of an impending overload condition. This

light indicates that the total signal exceeds eleven (11) times the full scale value. Measurements can be made for overloads up to 10 times full scale. Measurements under all these conditions will be most accurate if the zeroing process described in the Application Notes is followed.

Measurements Under Overloaded Conditions

Measurements under overloaded conditions can be made where it is desired to increase the null capability or to make the small quadrature signal level measurements. As stated previously, the signal levels in the Signal Channel may be 10 x the full scale reading as indicated by the Range Switch setting. Under some special conditions, these signals may exceed this 10 x specification by small amounts without overloading the amplifiers in the signal circuits. These signals, however, should never be increased beyond the level which will cause the overload indicator to light.

As an added convenience, the range vernier may be used to adjusted the indicated level as read on the meter. This may be used where signal levels are slightly in excess of full scale. This will allow the use of the full scale end of the meter when maximum accuracy occurs. It becomes advantageous to use this feature where E cos θ characteristic phase angle measurements are made.

SECTION III

THEORY OF OPERATION

Introduction

The schematic and block diagram of Figures 3.1 and 3.2 will serve to illustrate the principles of operation of the Phase Angle Voltmeter. The Phase Angle Voltmeter is a multi-function instrument and the following will describe each of these functions.

Voltmeter

When operating as a total and fundamental voltmeter, the instrument uses only the Signal Channel circuitry. The Signal Amplifier, in conjunction with the Range Attenuators, functions in a similar manner to any good quality AC Electronic Voltmeter. The signals applied to the input are amplified and fed to the meter rectifier circuit and indicated on the meter.

As a Fundamental Voltmeter, a harmonic filter is switched into the circuit and the meter will read only those frequencies within the pass band of the filter. See Figure 3.4 for filter characteristics.

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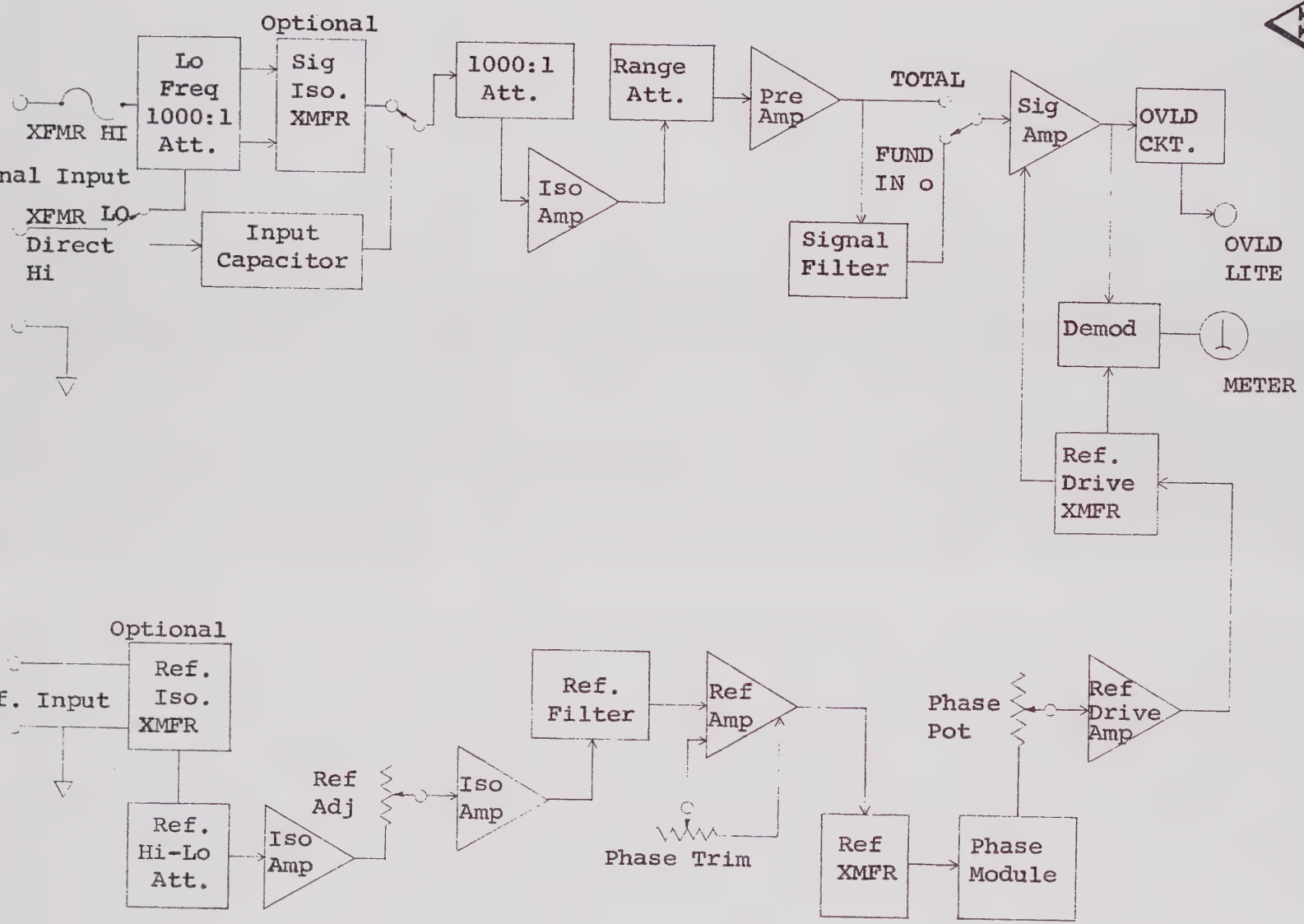


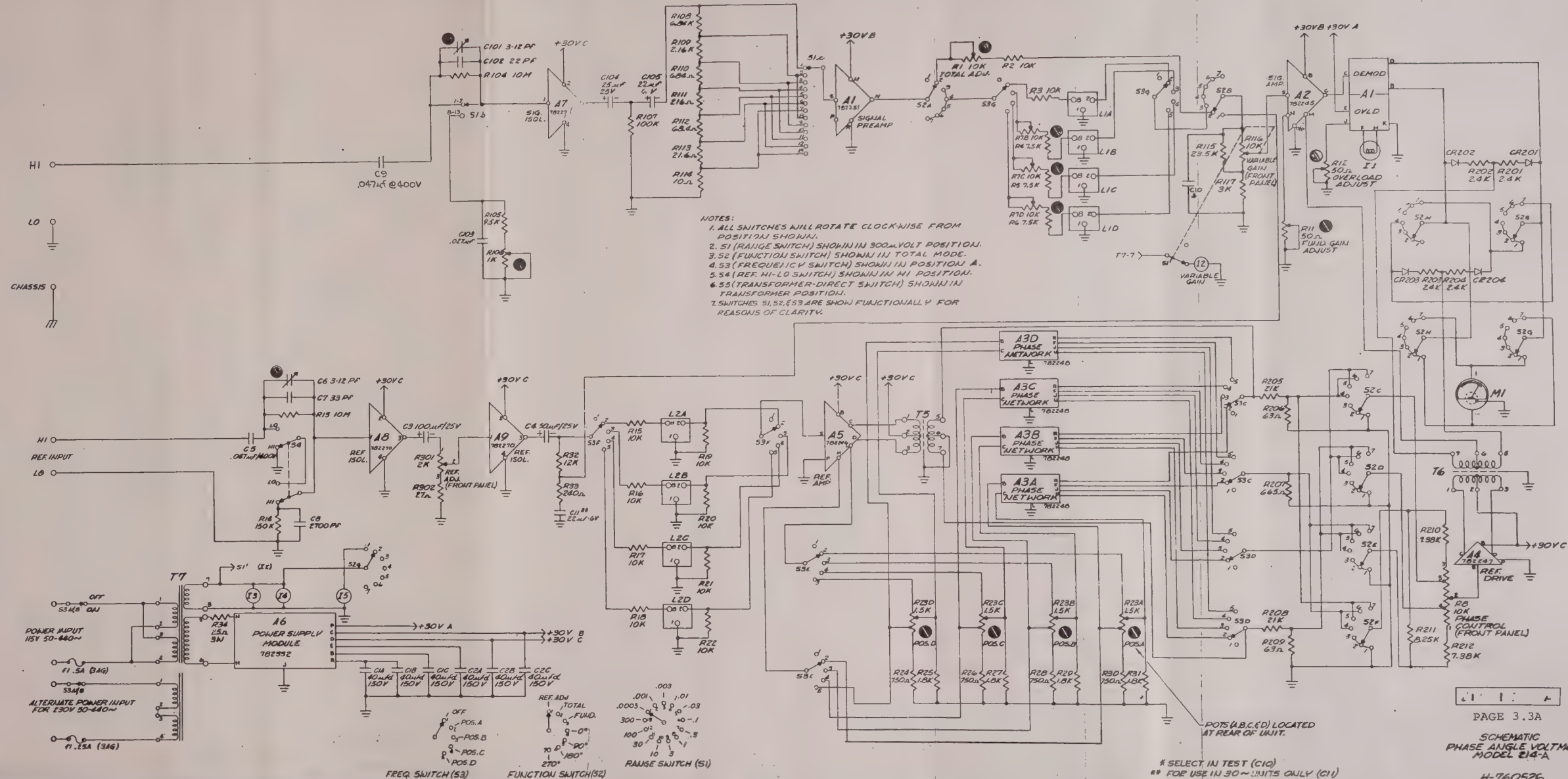
MODEL 214 - PHASE ANGLE VOLTMETER

BLOCK DIAGRAM

Figure 3.1
Page 3.2

As a Phase Angle Voltmeter, the Reference Channel is activated. The reference signal is amplified and phase shifted by the reference circuitry. The signal serves to gate the demodulator portion of the meter circuit. The relationship of this gating voltage to the signal being measured will determine the magnitude and the polarity indicated on the meter.

For those signals which are in-phase, a signal of maximum amplitude will be indicated and for those signals which are 90° out-of-phase (in Quadrature) a minimum signal will be read. Where the instrument is being used to read quadrature signals, these signals may exceed the indicated range by up to 10 x without overloading the signal amplifier circuits. This capability provides a means for much more accurate measurements of quadrature voltages and computation of phase angles.



PAGE 3.3A

SCHEMATIC
PHASE ANGLE VOLTMETER
MODEL 214-A

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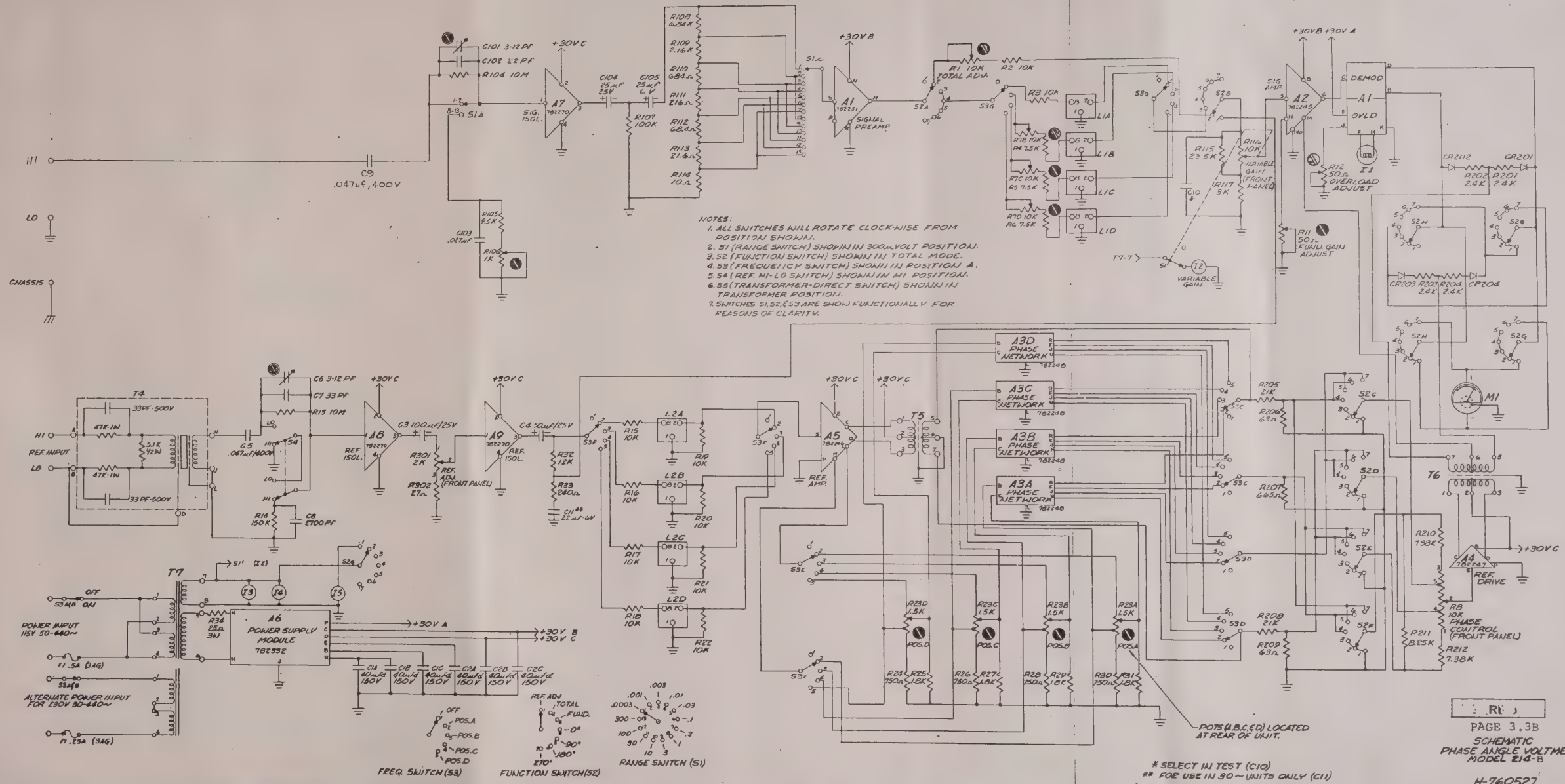

NOTES:
1. ALL SWITCHES WILL ROTATE CLOCK-WISE FROM POSITION SHOWN.
2. S1 (RANGE SWITCH) SHOWN IN 300mVOLT POSITION.
3. S2 (FUNCTION SWITCH) SHOWN IN TOTAL MODE.
4. S3 (FREQUENCY SWITCH) SHOWN IN POSITION A.
5. S4 (REF. HI-LO SWITCH) SHOWN IN HI POSITION.
6. S5 (TRANSFORMER-DIRECT SWITCH) SHOWN IN TRANSFORMER POSITION.
7. SWITCHES S1, S2, & S3 ARE SHOW FUNCTIONALLY FOR REASONS OF CLARITY.
* SELECT IN TEST (C10)
** FOR USE IN 50~ UNITS ONLY (C11)
POTS (A,B,C,&D) LOCATED AT REAR OF UNIT.
FREQ. SWITCH (S3)
FUNCTION SWITCH (S2)
RANGE SWITCH (S1)
PAGE 3.3B
SCHEMATIC
PHASE ANGLE VOLTMETER
MODEL 214-B
H-760527

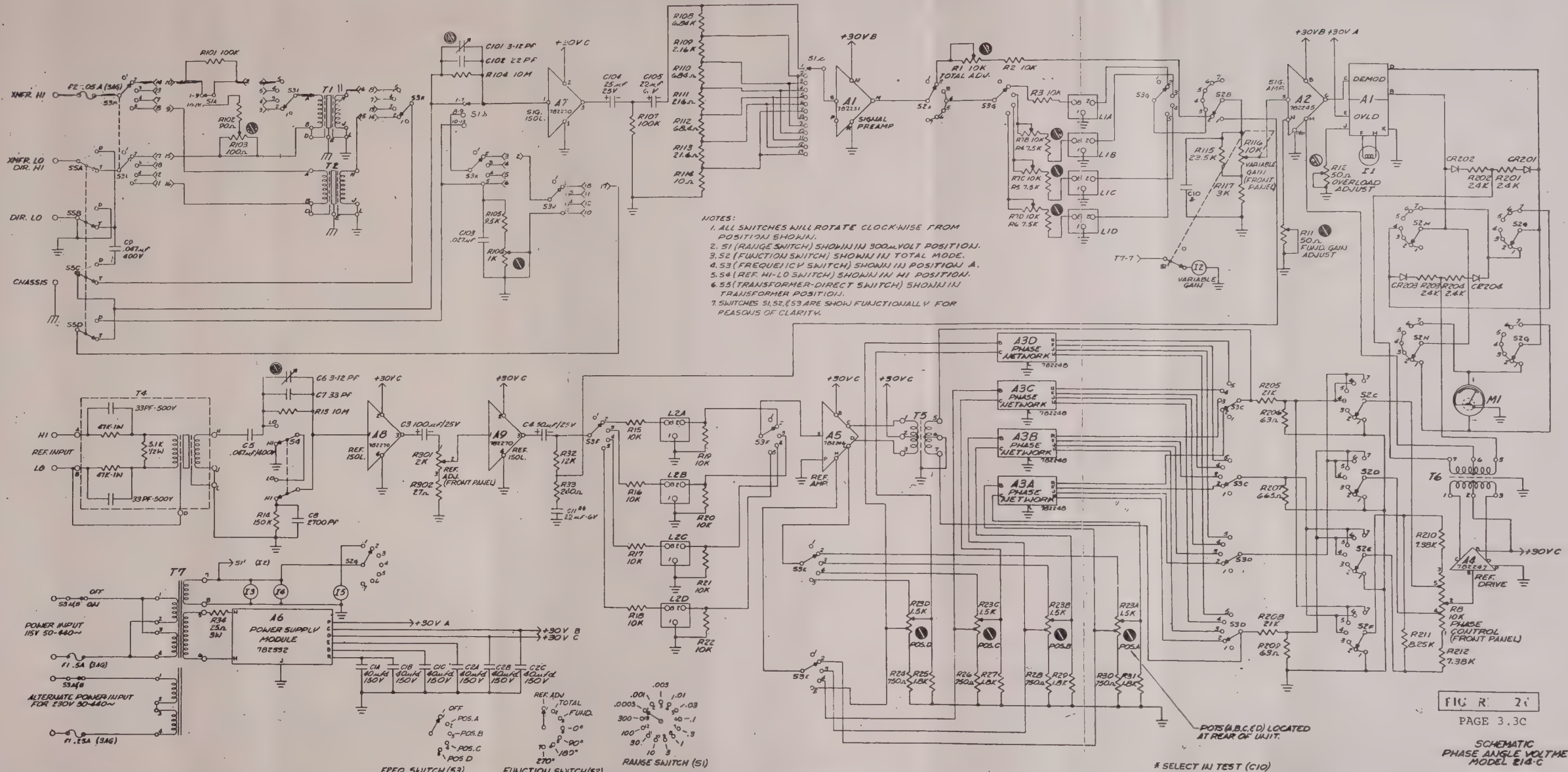
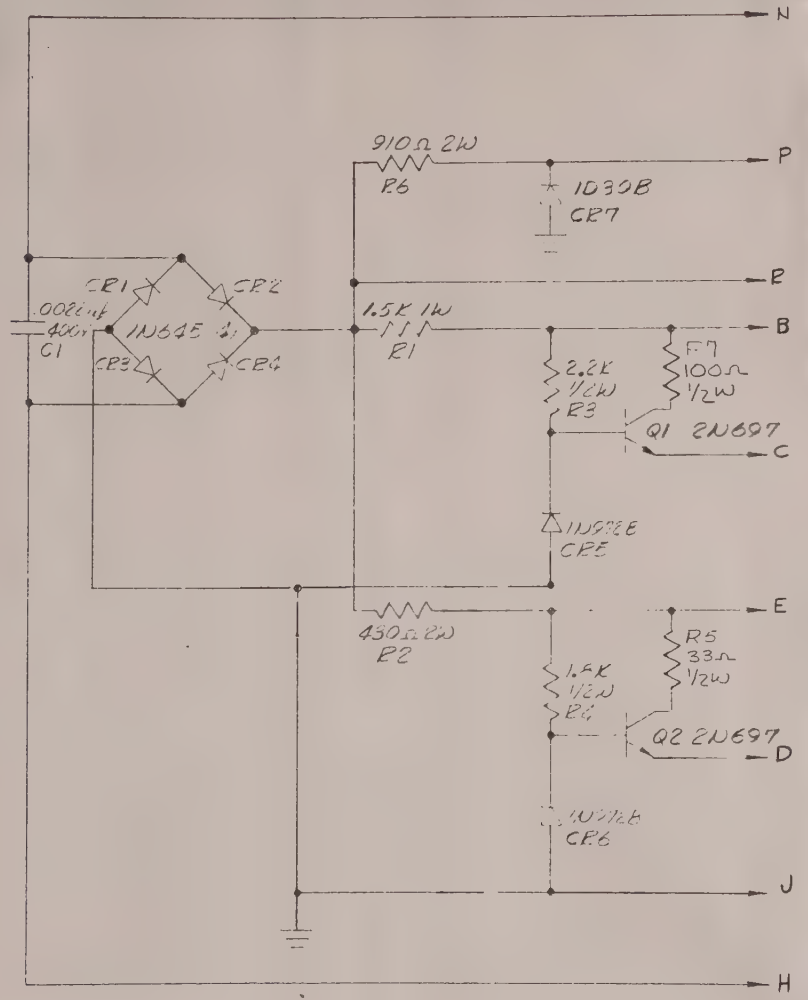


FIGURE 2

PAGE 3.3C

SCHEMATIC
PHASE ANGLE VOLTMETER
MODEL 214-C

H-760528



B-760435 A REV.
SHEET OF

REVISIONS				
ECN 3580	BM	12-9-65	1	A

ITEM	PART NUMBER	DESCRIPTION	REQ.

MATERIAL —//— SPEC
HEAT TREATMENT —//— SPEC
FINISH —//— SPEC

NEXT ASSEMBLY | USED ON

NORTH ATLANTIC industries, inc.

DRAWN BY BEM	DATE 6-15-65	TITLE SCHEMATIC POWER SUPPLY	
CHECKED QF	DRAFT. APP.		
PROJ. ENG	ENG. APP.		
SCALE #	TOLERANCES UNLESS OTHERWISE SPECIFIED FRACT. ± # DEC. ± # ANG ± #	B-760435 SHEET 1 OF 1	A REV.

Signal Input Attenuator

The amplifiers of the Model 214 always operate with the same basic sensitivity (300uv). This requires attenuators for reducing higher level voltages to this range. The input attenuator actually consists of two separate voltage divider networks. The first provides a 1000:1 reduction for voltages one volt and above. The second provides six attenuator ranges from 3:1 to 1000:1. This latter attenuator provides attenuation for signals up to and including 300mv and is added to the attenuation of the 1000:1 divider for signals between 3 volts and 300 volts.

At low frequencies, the 1000:1 attenuator ratio is determined soley by the resistors employed. At higher frequencies, capacitive compensation is necessary to compensate for circuit strays. This converts the attenuator to a capacitive divider at high frequencies. The crossover from resistive to capacitive attenuation occurs at approximately 600Hz. This attenuator when properly adjusted not only provides proper attenuation at both high and low frequencies but also has essentially zero phase shift over the rated frequency range. See Calibration Procedure, Section VI, for proper alignment.

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Amplifiers

The amplifiers used in the Model 214 Phase Angle Voltmeter are plug-in, silicon transistorized modules. All designs are based on the use of components well below maximum manufacturer's ratings to insure long-life and trouble-free operation. These modules are factory sealed, and in the event of failure, should be replaced as a unit. This seal should not be broken as this will void the North Atlantic Warranty. The individual amplifiers are described in the following paragraphs.

Isolation Amplifiers (Not Plug-In) - These modules contain very similar circuitry, each being modified slightly for a specific function. The basic function of this amplifier is to provide an accurate gain of unity, a high input impedance to the circuitry preceding it in order to prevent loading, and a low output impedance to the circuits which follow. The design of this amplifier is based on techniques using low noise field effect transistors.

Signal Pre-Amplifier - The Signal Pre-Amplifier is contained within the A1 Module, NAI #782251. This amplifier provides

a stable gain of 10 which is necessary for the 300uv sensitivity of the instrument. Large amounts of negative feedback is used so that its gain is controlled solely by stable precision resistors internal to the module. Its design is such that it provides a wide band frequency response with minimal phase shift and low noise.

Signal Amplifier - The Signal Amplifier is a circuit designed to have a very high gain-bandwidth product resulting in a low phase shift and high power gain. Its output drives the meter demodulator circuit. Large amounts of negative current feedback are used to eliminate the effects of diode non-linearities. The meter demodulator circuit is located partly within the A1 Module and partly on the Function Switch.

The Demodulator's phase-sensitive operation (see Figure 3.5) can be likened to that of a set of commutating switches. The reference signal alternately connects one side of the meter to ground through resistor R11 and then the other end on the reverse cycle of the reference. The

signal is, therefore, synchronously rectified through the meter movement. When the reference and signal are in-phase (Figure 3.5a) the average value will be a maximum and the meter will read a maximum. When the signals are 90^{o} apart (Figure 3.5b) the average will be zero and no reading will result. The equation governing this is:

$$I_{meter\ (avg)} = K\,E\cos\theta$$

where K = proportionality constant

E = RMS of signal

θ = angle between signal and reference

Demodulator saturation effects will limit this characteristic equation to the designed levels for the instrument. Under special conditions, such as are described in the appended Application Notes, the reference level is increased to improve accuracy for high signal levels. Measurements at the quadrature null point ($\theta = 90^{o}$) are relatively unaffected by saturation.

The response of the phase sensitive detector is limited to signals at the reference frequency as well as to odd order harmonics. Response for this type detector to odd

order harmonics will never be greater (usually less depending upon phase angle) than the fundamental response multiplied by a factor 1/n where n is the order of the harmonic. Where a Signal Channel filter is used, there is, of course, essentially no response to harmonics in the signals.

All other frequencies are rejected except for signals very near to the reference frequency and its odd harmonics. Here, the meter movement will oscillate between in-phase and 180 degrees out-of-phase and at a frequency proportional to the difference between the input frequency and the fundamental or third harmonic of the reference signal. Response of this nature is limited to frequency differences of about 5Hz (meter pass band).

The effect of reference harmonics is much less important than that of signal harmonics because the harmonic content can never do more than shift the point at which the diodes start to conduct. Expressed otherwise, there is an equivalent error in degrees which results from harmonics in the Reference Channel. For measurements using the phase shifter, the error can be removed by trimming. For measurements using E cos θ characteristic,

Effects of Distortion - The current through the meter in the latter circuit is proportional to the average value of the voltage waveform applied. Calibration of the meter in RMS is based on a ratio between the average and effective values of a true sinesoidal voltage. Deviation from a true sinewave may cause errors in the meter indication. Table I lists the range of possible errors due to the 2nd and 3rd harmonic distortion.

TABLE I - Errors Due to Harmonics in a Typical Average Detector

Harmonic Order	Harmonic Content	Error
2nd	10%	Nil
2nd	20%	0 to +2%
2nd	50%	0 to +10%
3rd	10%	-4% to +4%
3rd	20%	-6% to +8%
3rd	50%	-10% to +16%

The signal also drives the Overload Detector Circuit. The Overload Detector Circuit is designed to operate as a switch. When the signal level out of the Signal Amplifier Module (A2) exceeds a level of approximately 11 x full scale, the circuit will switch turning on the overload

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indicator. The signals amplifiers will operate up to and including a 10 x overload. The indicator is set to ignite above this level and ordinarily measurements may not be made as long as theindicator is lit. The amplifiers, however, have the capability of operate with larger signals without distorting.

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the effect is small because the meter reading as a function of current integrated over an entire cycle and the small error produced by distortion has a correspondingly small effect on the total current.

When used as a standard electronic voltmeter, the phase sensitive rectifier is switched to that of a full wave rectifier. Operation is identical to that of a full wave bridge power supply in which the meter movement acts as the load.

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A3, Phase Module - The A3 modules contain the Phase Shift circuitry required to generate the precision phase shifts in theReference Channel. These modules are supplied for specific frequencies as required by the individual user. They are designed to operate within specification over a ±5% bandwidth of the nominal frequency without readjustment. There may be 1, 2, 3, or 4 of these modules existing in the equipment. An output of 0°, 90°, 180°, and 270° is provided and is selected by the Function Switch. Angles in any quadrant are determined by connecting the phase potentiometer to any two adjacent points through the function switch. This provides a phase shift capability of 0° to 360° as determined by the Function Selector setting plus the Phase Dial (phase potentiometer) setting. (See Figure

These Phase Modules may be supplied as part of a Frequency Kit or individually. They are identified by either their NAI Part No. (782248-XX) or by their model number (PM10) followed by the operating frequency.

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A4, Reference Drive Module (NAI #782247) - It is the function of this module to accept phase shifted signals from the arm of the phase potentiometer and convert it to a push-pull driving signal, which performs the ultimate operation of gating the demodulator. The amplifier is designed to provide the necessary power gain while maintaining a minimal phase shift.

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A5, Reference Amplifier (NAI #782246) - The A5 Module is essentially the same as the A4 Reference Drive Amplifier except that its push-pull output is used to drive the phase shift networks. This amplifier has in its feedback network a channel phase control which provides small leading and lagging phase shifts. This control is used to align the phase shifts between the signal and reference channels to 0. It provides this phase shift without the introduction of any phase gradient so that once set at a frequency, it will not vary over a 5% bandwidth.

A6, Power Supply (NAI #782232) - See Schematic, Figure 3.3

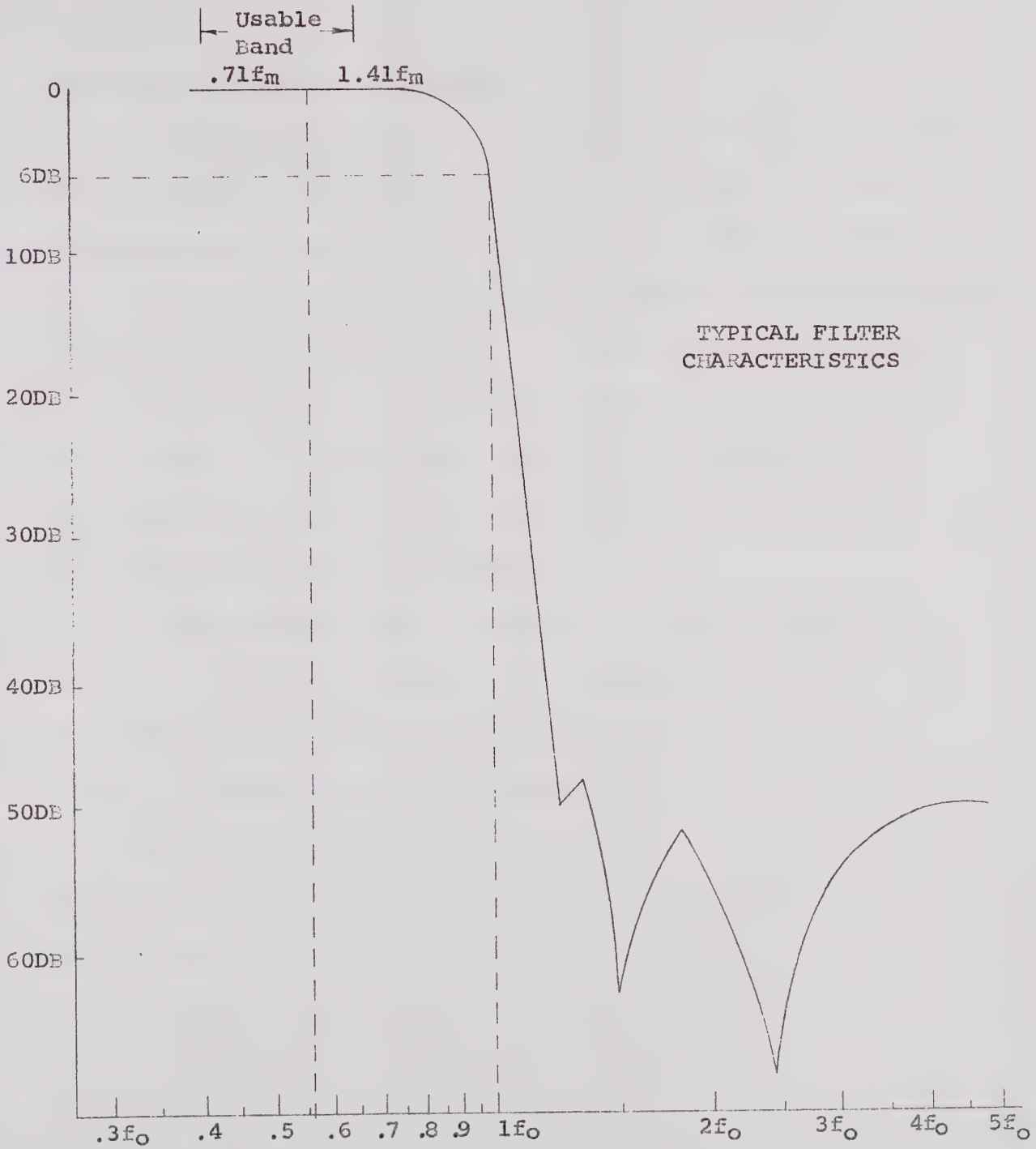
This module contains three +30V DC sources. Two of these 30V sources are well regulated, well filtered, and are used individually to supply the Signal and Reference Channels.

The third 30V source is zener regulated and is used to supply the overload circuitry. Note that the filtering for the power supply is accomplished by means of electrolytic capacitors C1 and C2 mounted on the chassis.

Filters

The filters used are matched, plug-in low pass types and are supplied in pairs. The filters are operated in a restricted portion of the pass band in order to maintain, over this band, the amplitude gradient within the instrument's specifications and to restrict the phase variation. Table II describes all filters available and their useable bands and Figure 3.4 is a typical filter response. Referring to Table II, F_m designates the geometric mean frequency of the useable band. The upper frequency limit is determined by the amplitude vs. frequency characteristic. Lower frequency limit is determined by the amount of rejection of the third harmonic of this frequency.

NOTE: When making phase-sensitive measurements, the detector circuit inherently has a high second harmonic rejection (approx. 55DB) and 10DB additional rejection of the third harmonic. This additional harmonic rejection is individually added to the filter rejection when operating in any phase-sensitive mode.



TYPICAL FILTER
CHARACTERISTICS

Figure 3.4
Page 3.19

Isolation Transformers (Optional)

The Signal Isolation Transformers are designed to operate within a limited band. The low frequency isolation transformer (Model TM41) will operate over a band of from 30Hz to 2.5KHz. The high frequency transformer (Model TM42) will operate over a band of frequencies from 2.5KHz to 20KHz. Frequencies of operation, as specified by the user, will determine whether the low frequency, high frequency, or both transformers will be required. These transformers may be used for isolating signal inputs for both single ended and differential measurements.

The maximum voltage limitation of these transformers is expressed in terms of F where F is the operating frequency. The lower frequency transformer (TM 41) is rated at 0.75F up to a maximum of 300V and the high frequency transformer (TM42) is rated at 0.12F up to 300V maximum. When used in the Model 214C, an additional input attenuator (see Frequency Change Section, Section IV) permits their use over the full rated voltage range of the instrument.

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Reference isolation, being much less critical than the signal isolation, requires only a single transformer be used. This transformer (Model TM40) is used on both the 214B and 214C Models.

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Frequency Switch

The Frequency Switch in the Model 214C only has been constructed so as to provide maximum flexibility in the field. In the event that the frequency of any given channel is to be changed, the jumpers on TB1 and TB2 in the Frequency Switch may be changed. As previously noted in the Frequency Change Section, Page 4.1 , this is required to include the proper signal isolation transformer for a given frequency. The instruments as wired at the factory will have these jumpers arranged properly for the frequencies which are factory installed. If a frequency is to be added or changed in the field, these jumpers may be changed by referring to the frequency change, Section IV, Page 4.1.

NOTE: An adjustable stop is provided on the Frequency Switch to prevent rotation to unused portions in instruments which use less than four channels. It consists of a stop bar clamped to the switch shaft and a fixed stop pin located in the sub-panel. This stop may be readjusted in the following manner when more channels are to be used.

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Remove the bottom cover of the instrument. Loosen the set screw which clamps the stop bar on the switch shaft. (This is clearly accessible from the underside between the front panel and the sub-panel). Rotate the switch to the most clockwise position to be used. Press the stop bar against the stop pin and re-tighten the set screw. The stop will now prevent the switch from rotating beyond the position selected.

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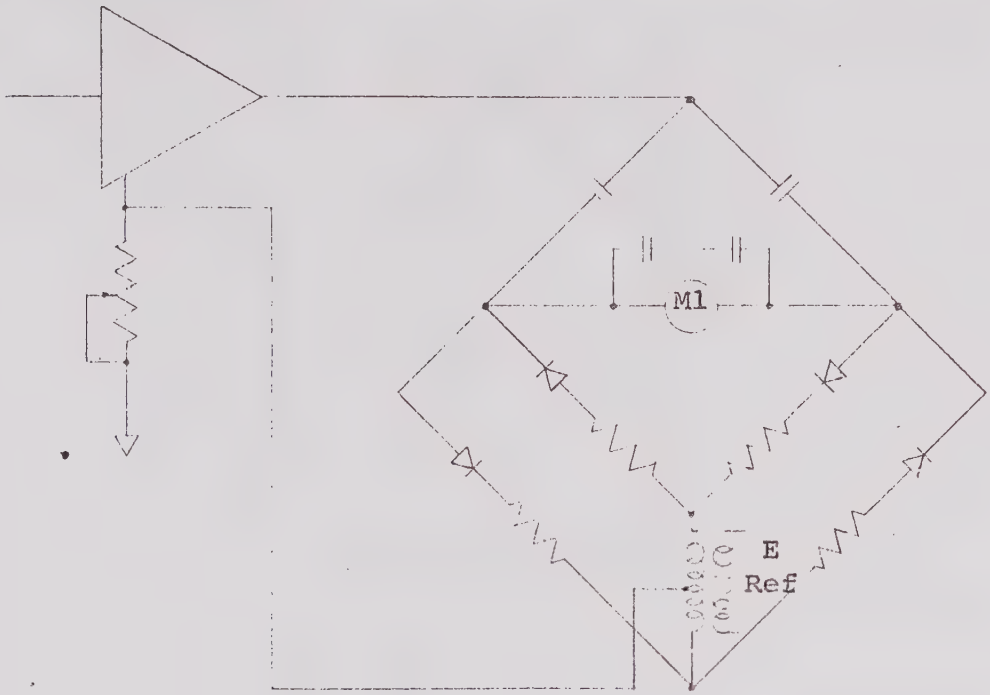
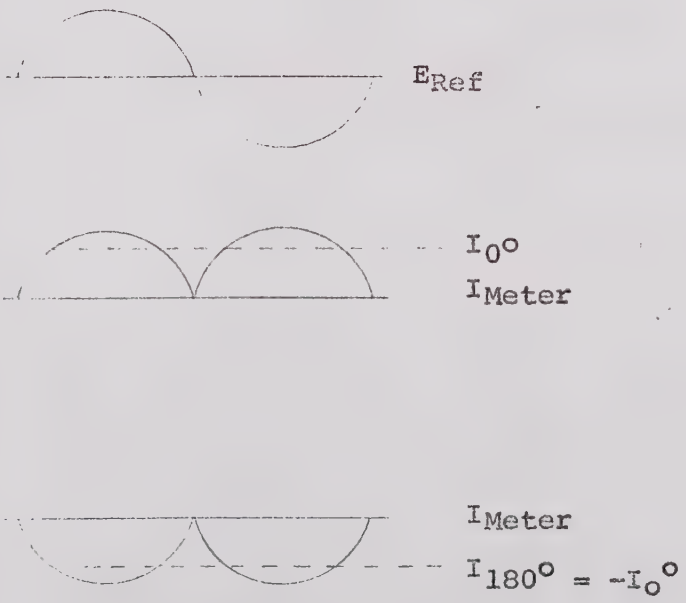
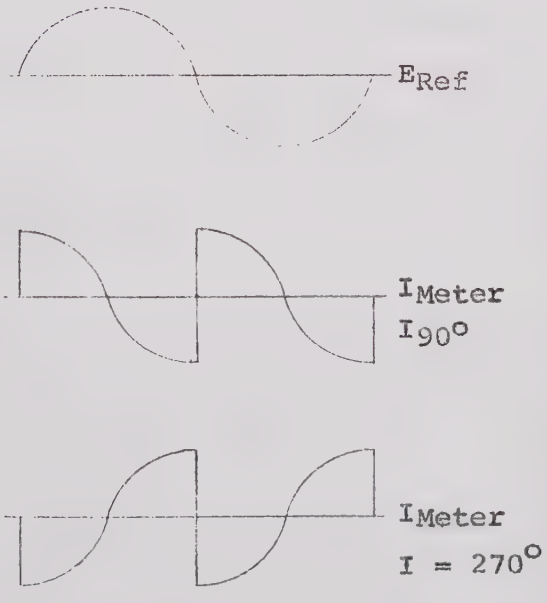
SIMPLIFIED PHASE SENSITIVE DEMODULATOR



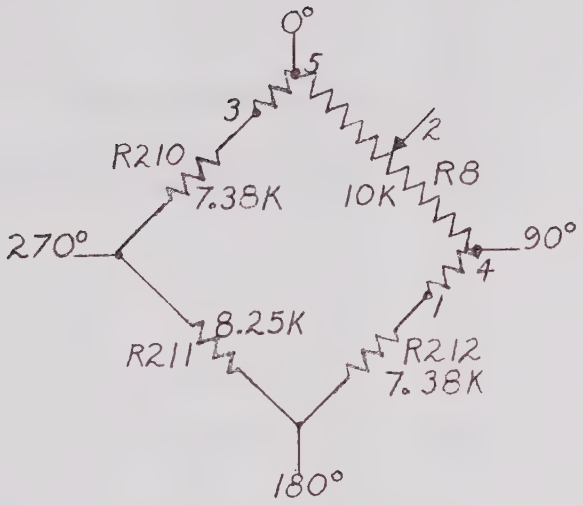


IN PHASE (0°/180°)
(A)

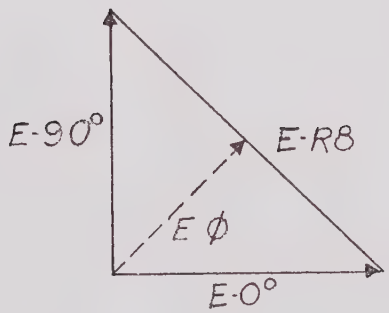


QUADRATURE (90°/270°)
(B)

Figure 3.5
Page 3.24



PHASE SHIFT BRIDGE



VOLTAGE VECTOR AT PHASE POTENTIOMETER

$E\text{-}0^{\circ} = E90^{\circ}$

$\theta = \theta \text{ Max } \frac{\text{Tan } \phi}{1 + \text{Tan } \phi}$

ϕ = Electrical Phase Angle

θ = R8 Shaft Angle

The voltage E-R8 appears across the Phase Potentiometer R8 between the taps, terminals 4 and 5. When $E0^{\circ}$ is set equal to $E90^{\circ}$, the electrical angle Eϕ is a non-linear function of the potentiometer shaft angle. This is compensated by a non-linear phase dial. This function is described by the equation shown.

The 90° angular rotation is shifted to any quadrant by the four corners of the bridge being rotated to cause the desired quadrant voltage to appear across the potentiometer. This is performed by the function switch.

Figure 3.6

SECTION IV

FREQUENCY MODIFICATION

MODEL 214 PHASE ANGLE VOLTMETER

The Model 214 Phase Angle Voltmeter has been specifically designed to allow the change or addition of frequencies of operation by changing or adding plug-in modules. The following information is a description of the modules and instructions for making these changes or additions.

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Isolation Transformers..... 4.5

Frequency Switch (S3)..... 4.7

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Figure 4.5..... 4.20
Figure 4.6..... 4.21
Figure 4.7..... 4.22

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TM42 - Signal Isolation Transformer	For signal isolation in the Model 214C in the frequency range of 2.5KHz to 20KHz.

*Actual frequency of operation, i.e., KM30-400Hz

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PLUG-IN MODULE KIT

AND TRANSFORMER GUIDE

	APPLICATION
KM30-Frequency*	For change or addition of

Frequency Module Kit, KM-30 (See Figure 4.1 for Outline)

The Frequency Module Kit, KM-30, consists of:

1. PM-10 Phase Module
2. FM-21 Filter (supplied in matched pairs)
1. Frequency decal (for frequency identification at Frequency Switch on front panel).

N O T E

For frequencies below 60Hz, Capacitor C11 is included. This must be installed in the instrument on the underside of the chassis. A pair of terminals is provided for mounting. The jumper across these terminals must be removed and the capacitor soldered in place. The capacitor, being polarized, must be installed with the negative terminal to ground.

It should also be noted that connectors J3B and J3C may be moved within the chassis cutout to provide space, where necessary, to accommodate the various modules of differing sizes. Ordinarily, this will not be necessary except for low frequency modules in some special cases.

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Isolation Transformers (Optional) TM40, TM41, TM42
See Figure 4.2 for Outline

In order to allow the use of the Model 214 Phase Angle Voltmeter with isolated or floated inputs, the following special transformers were designed:

TM40, Reference Isolation Transformer (Used in Model 214B and 214C)

This transformer is designed for isolating the reference input signals and will operate over the entire phase-sensitive frequency range of the Model 214. The Models 214B and 214C are equipped with a connector to receive this plug-in transformer.

TM41, Signal Isolation Transformer, Low Frequency (Used in 214C)

This is a well-shielded, high quality transformer designed to operate within the frequency band of 30Hz to 2.5KHz. The maximum voltage rating of this transformer is limited to 0.75f (where f is the operating frequency).

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up to a maximum of 300V. The 214C is equipped with a connector to receive this plug-in transformer.

TM42, Signal Isolation Transformer, High Frequency (Model 214C)

This transformer is similar in design to the TM41 transformer except that its frequency range is 2.5KHz to 20KHz and its voltage rating is 0.12f (where f is the frequency of operation) up to 300V maximum. It also plugs into a connector provided on the 214C chassis.

The specific connections of the Signal Isolation Transformers are described in the following instructions for Model 214C.

Note TM41 and TM42 are protected from overload by fuse, F2, which is a .05A, 3AG fuse, with a minimum resistance of 300 ohms.

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Frequency Switch (S3). See Figure 4.3

The Frequency Switch (S3) in the Model 214C has been constructed so as to provide maximum flexibility in the field. In the event that the frequency of any given channel is to be changed, the jumpers on TB1 and TB2 may be changed. The instruments as wired at the factory will have these jumpers arranged properly for the frequencies which are factory installed. If a frequency is to be changed or added, the change or addition of jumpers may be made by referring to the Frequency Change for 214C (Page 4.15).

The following is a discussion of the switch and jumper functions (See Figure 4.3).

The jumpers on TB2 are primarily for connecting the input signals to the proper transformer depending on the frequency of operation at any given position of the Frequency Switch. In addition the alternate or low frequency attenuator may be removed or connected as required for low frequency performance. This attenuator is required by the voltage limitation (f rating) of the low frequency transformer.

The jumpers on TB1 perform three separate functions:

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1. The first is to select the desired transformer output.
2. The second is to by-pass the standard 1000:1 attenuator in positions 10-13 of the Range Switch (S1) when the alternate or low frequency attenuators switched into the circuit as in Case 4 or to maintain the standard 1000:1 attenuator connection as in Cases 1, 2, and 3.
3. The third is to provide shielding between Pins 17 and 3 as in Cases 1, 2, and 3; or as in Case 4 a series connection through S3J and S3K for by-passing the standard 1000:1 attenuator as described in 2 above.

NOTE:

When the 214C is connected as above, it will not be possible to measure high voltages at low frequencies in the TOTAL Mode with the Isolation Transformer in the circuit. If it is desired to use the instrument in this manner, the alternate 1000:1 attenuator may be connected

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as in Case 4 (Figure 4.7). This should be done in the lowest frequency channel.

It must be recognized that this type of connection will cause a deterioration of the common-mode specification of the instrument. The degree of deterioration will depend on the frequency of operation.

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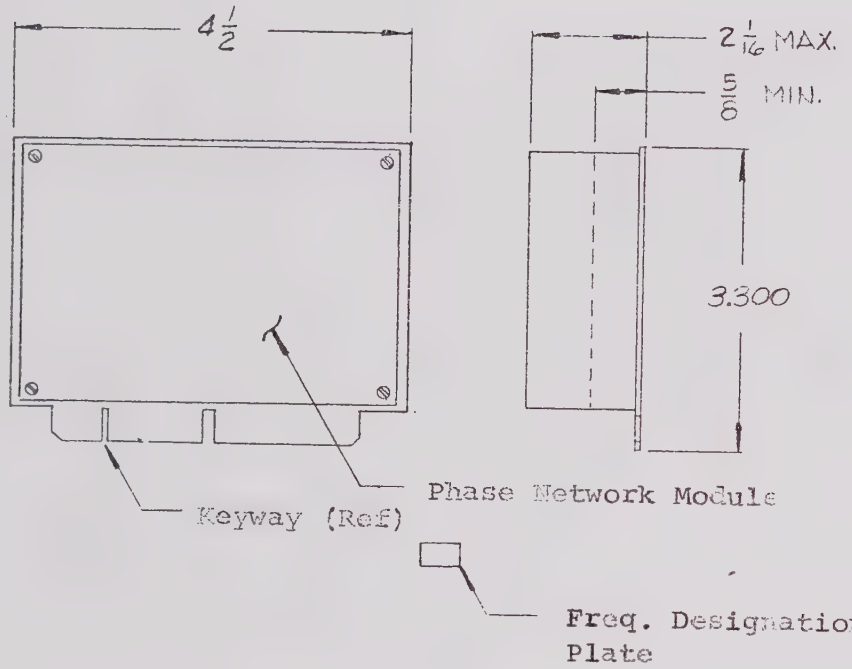
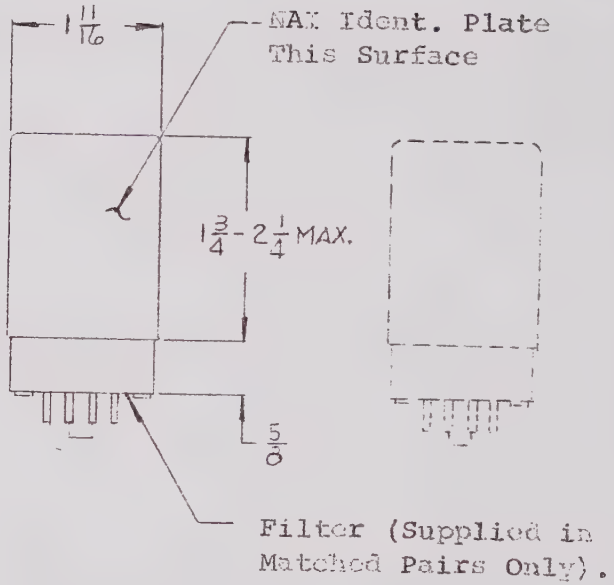
PM 10



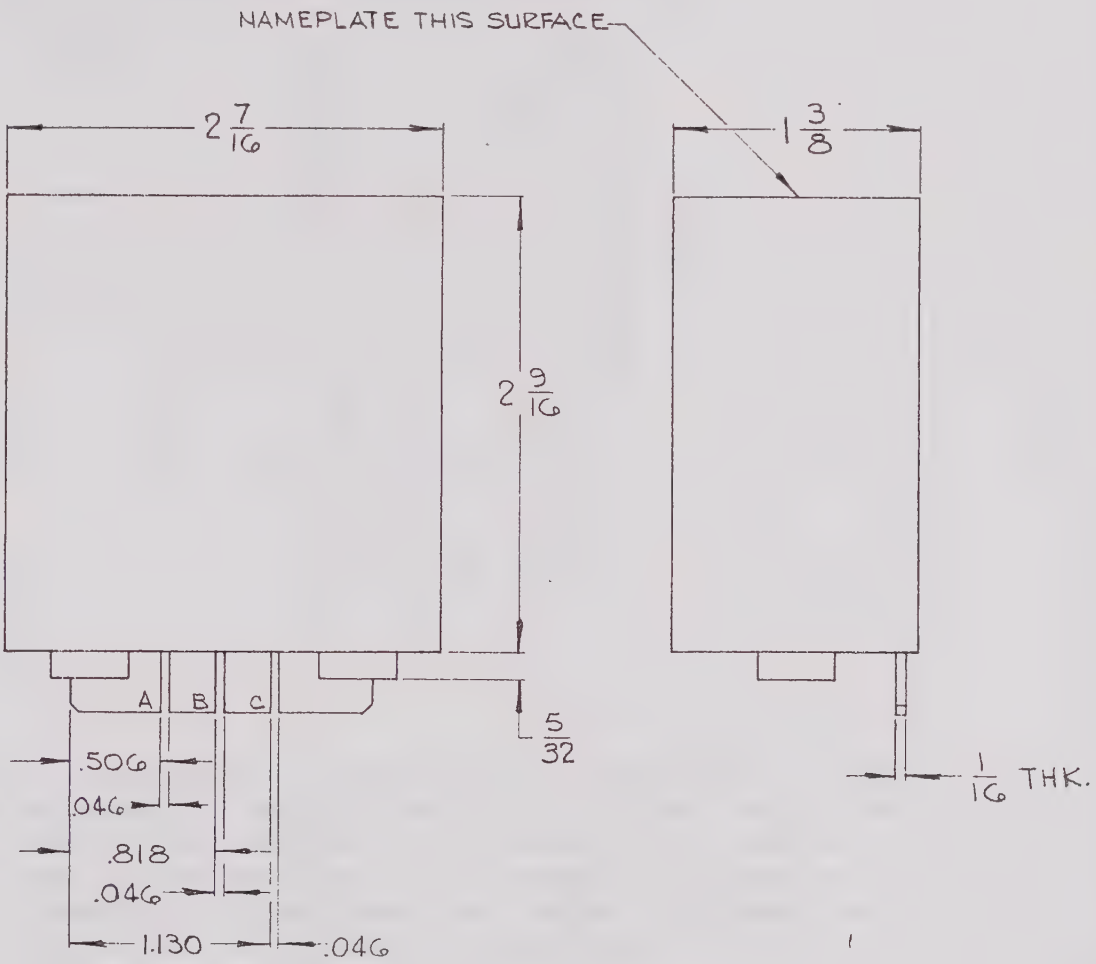
FM 21



PLUG-IN MODULE KIT

KM 30

Figure 4.1
Page 4.10



ISOLATION TRANSFORMER OUTLINE

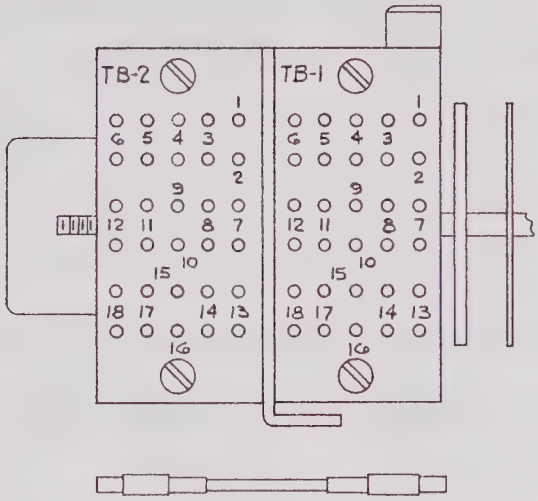
This outline applies to all three Isolation Transformers. To prevent plugging a transformer into the wrong connector, each type is slotted as follows:

TM42 - Slot A
TM41 - Slot B
TM40 - Slot C

Figure 4.2
Page 4.11

FREQUENCY SWITCH (S3)

TERMINAL BOARD CONFIGURATION



Jumper, NAI #202823

This is the physical arrangement of the terminal boards located on the Frequency Switch (S3). The jumper shown is universal and may be used to connect any pair of terminal points together. The number of jumpers will vary depending on the range and number of frequencies used. See text of Frequency Change Section for connection instructions.

Figure 4.3
Page 4.12

Frequency Changes - Model 214A and 214B

The basic design of the Model 214 Phase Angle Voltmeter is such that 4 separate frequency channels may be used. In the event that the user wishes to change any of these frequencies after obtaining the instrument, the following procedure must be adhered to. A frequency of operation for an individual channel may be changed by replacing the phase module and the filters associated with that channel. This may be accomplished by simply removing the phase module, Model PM-10, and filters, Model FM-21, from their sockets and replacing them with the proper components.

The phase modules are factory calibrated and require no adjustment. It may be necessary to make some adjustment to the instrument due to variations in filter characteristics. The following adjustments can be made without any calibration test equipment.

Phase Adjustment

Connect any convenient signal of the module frequency to both the reference input and signal input terminals. Set the Frequency Switch to the proper position and adjust the Reference Level Control. Set the Range Switch

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to the most sensitive range before the overload light turns on. This is to achieve maximum phase sensitivity (Page 2.20). Switch the Function Switch to the 90° position and the Phase Dial to 0°. Adjust R23-A, B, C, or D located on the rear panel (corresponding to the channel affected) so that a null is achieved. The instrument is now phase aligned.

Amplitude Adjustment - (This adjustment will rarely be necessary but should be checked and adjusted if maximum precision is desired).

Set the "Frequency Switch" to the position in which the calibration is desired and the "Function Switch" to FUND.. Connect a signal to the input terminals which will result in a near full scale deflection on any range. Note this reading. Adjust R7-B, C, or D located on the chassis for the channel affected so that the deflection is identical to that in the TOTAL position.

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In the event the replacement takes place in Channel A, it will be necessary to readjust R11 (Fundamental Gain Adjust). If this latter adjustment is made, it will be necessary to recheck the adjustment of R7-B, C, and D (individual filter gain adjustments).

Frequency Change - Model 214C

In those instruments containing signal isolation (Model 214C) it should be noted that there are one or two transformers, each for specific frequency bands. The frequency to which the user wishes to convert must be associated with the isolation transformer which covers that frequency. The frequency calibration procedure applies in addition to the information in the following paragraphs. The low frequency transformer (T1) may be used for frequencies from 30Hz to 2.5Hz. The higher frequency transformer (T2) is for use between 2.5KHz and 20KHz.

In the event that a channel must be converted for use with a frequency which is in a different band (using a transformer), the jumpers at the top of the Frequency Switch, S3 (See Figure 4.3)

must be changed. Specific instructions for changing these jumpers are described in the following paragraphs.

CASE 1: (See Figure 4.4) - All four channels are between 400Hz and 2.5KHz.

For frequencies between 400Hz and 2.5KHz, jumpers are connected such that T1 only (TM41) is in the circuit. For frequencies above 400Hz, the alternate or low frequency 1000:1 attenuator is by-passed (TB2-14 to 3). Where this attenuator is not used, the standard 1000:1 attenuator must be connected in position 10 through 13 of the Range Switch. This is accomplished in this case by connecting all of the terminals at S3K together. Jumpers S3J are to ground unused terminals (TB1-10, 12, 11, 18).

Connect:

	TB1	
16-14	3-4	10-12
14-13	4-5	12-11
13-7	5-6	11-18
7-8		

	TB2	
14-3	3-4	15-17
13-14	4-5	17-18
7-13	5-6	18-12
8-7		12-11

CASE 2: (See Figure 4.5) - All four channels are between 2.5KHz and 20KHz.

For frequencies between 2.5Hz and 20KHz, jumpers are connected such that T2 only is in the circuit. The low frequency 1000:1 attenuator is again by-passed and the jumper arrangement at the standard 1000:1 attenuator (TB1-3,4,5,6) are the same as Case 1. TB1-10, 12, 11, 18 are jumpered to ground unused terminals.

Connect:

TB1		
14-13	3-4	10-12
13-7	4-5	12-11
7-8	5-6	11-18
8-15		

TB2	
14-13	17-18
13-7	18-12
7-8	12-11
8-9	11-16

CASE 3: (See Figure 4.6) - 2 channels between 400Hz and 2.5KHz
2 channels between 2.5KHz and 20KHz.

For frequencies between 400Hz and 20KHz where jumpers are connected to use both T1 and T2. The low frequency 1000:1 attenuator is by-passed and the jumper arrangement at the standard

1000:1 attenuator (TB1-3,4,5,6) are the same as Cases 1 and 2.

TB1-10, 12, 11, 18 are jumpered to ground unused terminals.

Connect:

	TB1	
16-14	3-4	10-12
14-13	4-5	12-11
7-8	5-6	11-18
8-16		

	TB2	
14-3	15-17	3-4
14-13	17-18	
7-8	12-11	
8-9	11-16	

CASE 4: (See Figure 4.7) - 1 channel below 400Hz (Channel A)

1 channel between 400Hz and 2.5Hz (Channel B)

2 channels between 2.5Hz and 20KHz (Channels C and D)

For a combination where a frequency below 400Hz is to be included. Both transformer are connected much in the same manner as Case 3. This requires that the 1000:1 low frequency attenuator be used to limit the voltage, due to the f rating of the transformer (See Transformer, Page 3.20). Particular attention must be paid to

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the jumper connections at S3J and S3K. In this case, the standard 1000:1 attenuator is switched out of the circuit in positions 10 to 13 of the Range Switch (S1). At the same time, the low frequency 1000:1 attenuator is switched into the circuit. This will provide the same overall sensitivity of the instrument, while limiting the low frequency voltage applied to the transformer. Note that where a 30Hz channel is to be used, only three channels are available due to the large size of the phase module.

Connect:

	TB1	
16-14	2-3	17-18
14-13	4-5	10-12
7-8	5-6	12-11
8-15		

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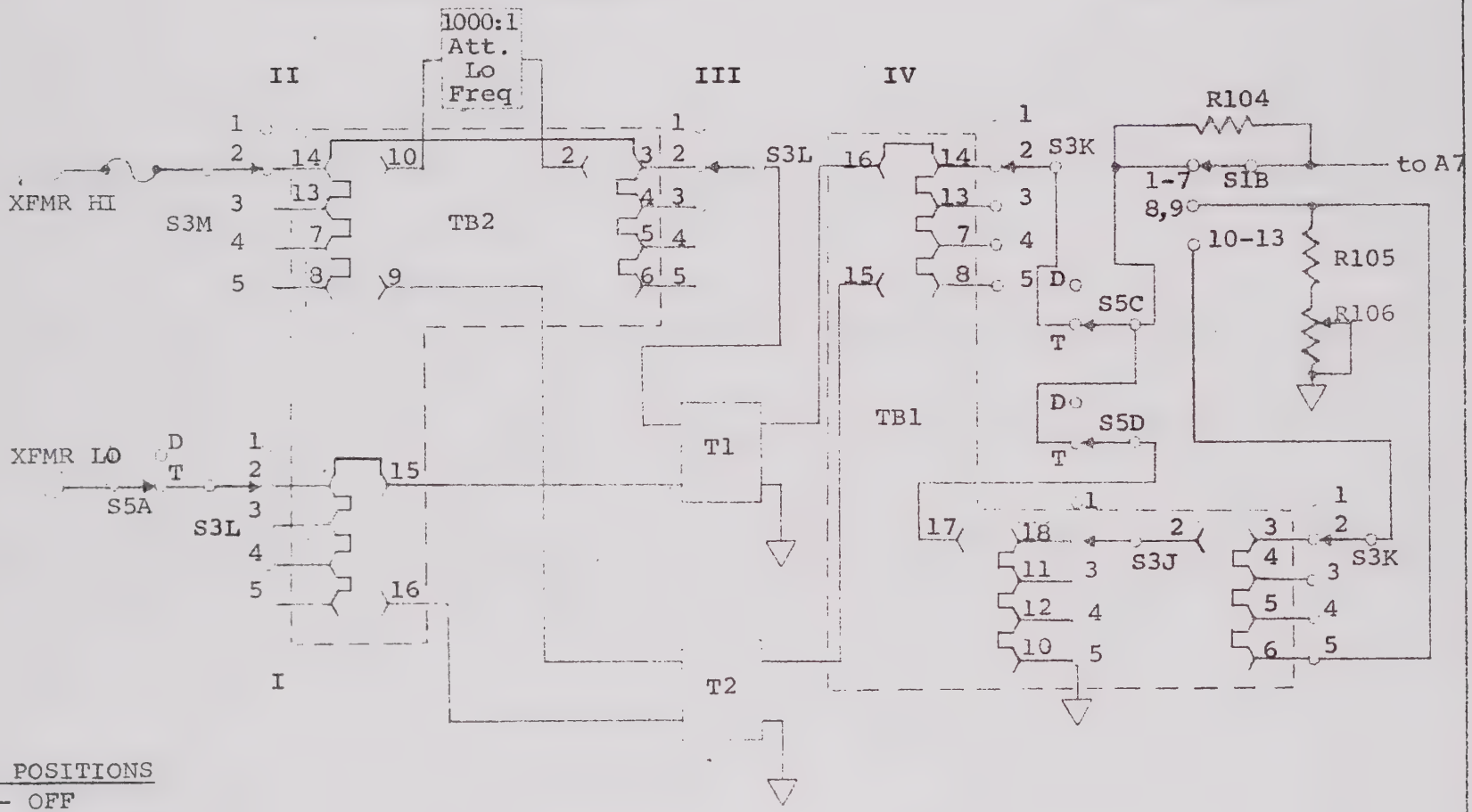

S3 POSITIONS

1 - OFF
2 - A 400Hz
3 - B 800Hz
4 - C 1200Hz
5 - D 2400Hz

JUMPER CONNECTION DIAGRAM
CASE 1, 400Hz to 2.5KHz
Figure 4.4

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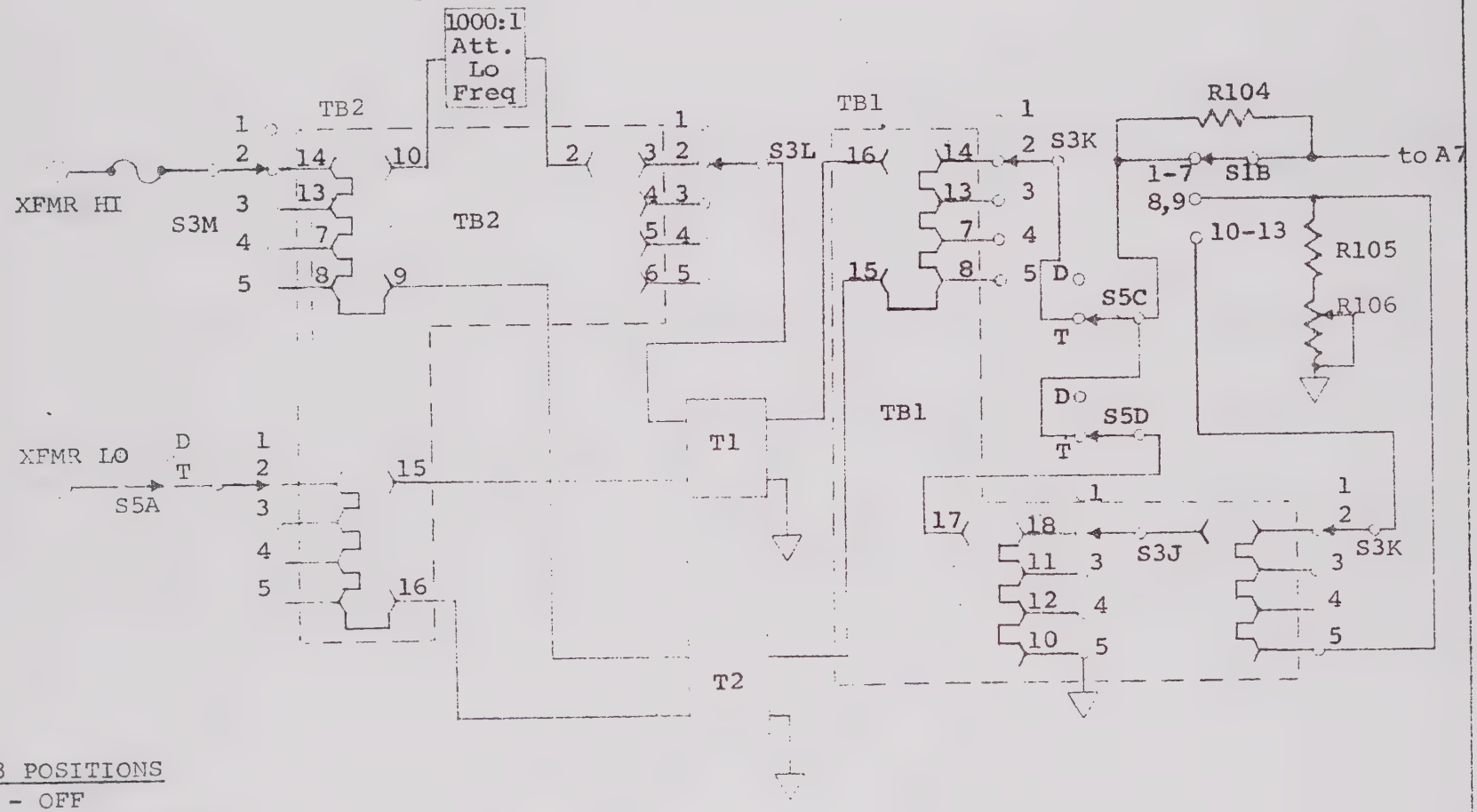

S3 POSITIONS

1	- OFF	
2	- A	3.2KHz
3	- B	4.8KHz
4	- C	10KHz
5	- D	20KHz

JUMPER CONNECTION DIAGRAM
Case 2. 2.5KHz to 20KHz
Figure 4.5

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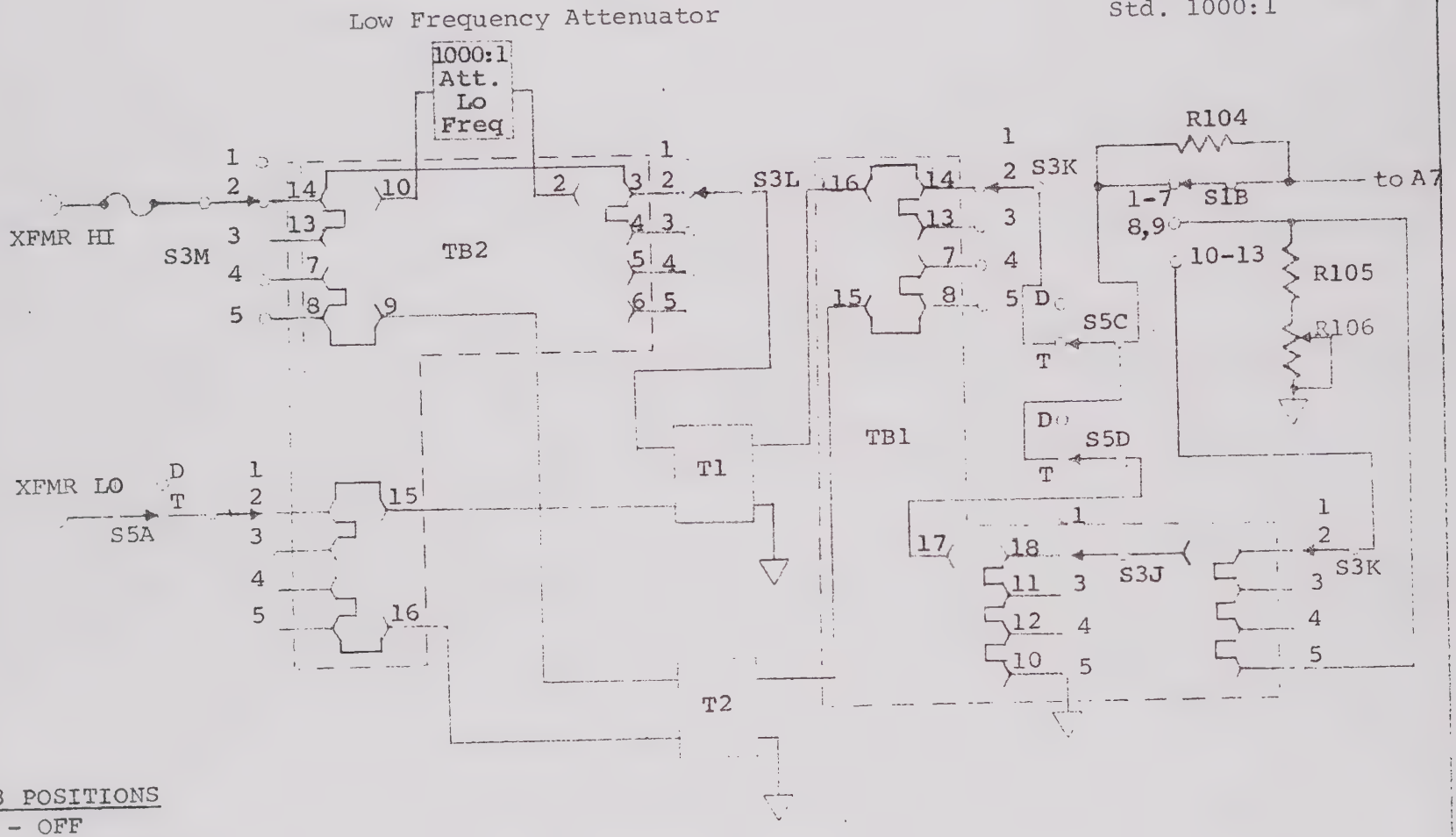

S3 POSITIONS

1 - OFF
2 - A 400Hz
3 - B 1KHz
4 - C 10KHz
5 - D 20KHz

JUMPER CONNECTION DIAGRAM

Case 3, 400Hz to 2.5KHz
2.5KHz to 20KHz

Figure 4.6

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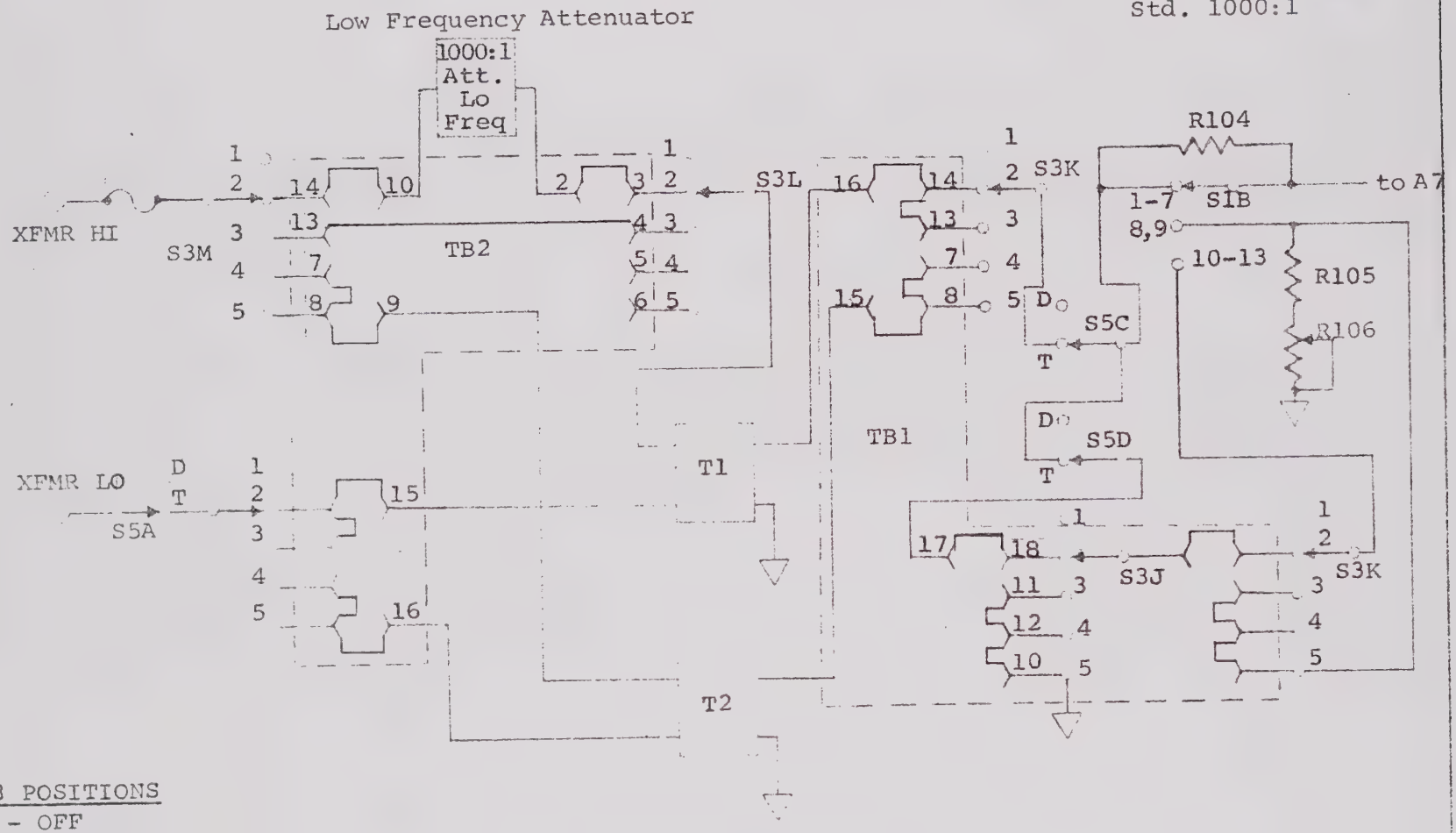

S3 POSITIONS
1 - OFF
2 - A 60Hz
3 - B 400Hz
4 - C 3.2Hz
5 - D 10Hz

JUMPER CONNECTION DIAGRAM
Case 4. under 400Hz
400Hz to 2.5Hz
2.5Hz to 20Hz
Figure 4.7

TABLE II

Model No.	Part No.	Useable Band
FM-21	782334-1	55Hz to 110Hz
FM-21	782334-2	110Hz to 220Hz
FM-21	782334-4	525Hz to 1050Hz
FM-21	782334-5	880Hz to 1760Hz
FM-21	782334-6	1760Hz to 3520Hz
FM-21	782334-7	3520Hz to 7040Hz
FM-21	782334-8	7040Hz to 14.1KHz
FM-21	782334-10	265Hz to 530Hz
FM-21	782334-11	27.5Hz to 55Hz
FM-21	782334-12	14.2KHz to 28.2KHz

Filters may be specified either by NAI Part Nos. or by Model Nos followed by the operating frequency.

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SECTION V

MAINTENANCE

The following section contains instructions for the general maintenance of the Phase Angle Voltmeter. All alignment procedures are described in Section

Cover Removal

In order to service or change frequencies, it is necessary to remove the top cover of the instrument. In order to remove the top cover of the instrument, it is necessary to remove 5 screws. For additional trouble shooting and maintenance, it may become necessary to remove the bottom cover of the instrument which may easily be accomplished by removing 5 screws.

Replacement of Modules

With the top cover removed, remove the module hold-down bracket to replace any of the modules in their sockets. Care must be exercised to insure that a module is replaced with the same type.

Filters may be replaced or changed by removing the screws from the underside and unplugging the filter to be replaced. For repair or replacement, the exact replacement filter pairs must be used. For frequency change, the filter for the frequency of operation should be plugged into the proper socket designated by Channels A, B, C, or D. The hold-down screws should then be replaced.

Where a frequency change is to take place, the proper phase module must also be plugged into the proper J3 socket for the given channgels which can be activated are limited by the physical dimensions of the 30∿ phase module. A 30∿ phase module should be plugged into Channel A (J3A) which will allow the use of additional channels C and D (B socket will be inaccessible).

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Power Supply

The Power Supply, being the only module containing components with appreciable operating stress, may require occasional maintenance. The components within the supply are generally of the most dependable type available. However, should it become necessary to replace any of these components, only identical components should be used. The module may be easily opened by removing it from its socket and removing the 4 screws holding the cover in place. All precautions consistent with good practice should be exercised in the replacement of any component.

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Replacement of Chassis Components

There are a limited number of components which are mounted directly to the chassis, all of which are easily accessible. In the event that any of these must be replaced, normal precautions consistent with good manufacturer practice should be followed.

There are a number of components which are mounted to switch assemblies. In the event there is a failure in any of these components, it is recommended that the switch be replaced as a complete assembly where possible.

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Replacement of Fuses

There are two fuses used in the Model 214 Phase Angle Voltmeter. The first fuse is a power fuse mounted on the rear panel of the unit and may easily be replaced by removing the fuseholder cap. This fuse will normally be a .5 amp fuse, Type 3AG, for those instruments which operate with 115V power. For those instruments which operate with 230V power source, this fuse should be a .25 amp, Type 3AG.

The second fuse is used only in Model 214C instruments containing the optional signal isolation transformer. This is a .05 amp fuse which is located on the front panel and may be replaced by removing the cap from the fuseholder. A spare is located adjacent to this fuse in a similar fuseholder. Replacements for this fuse should not have a resistance greater than 30Ω as this will create errors in excess of the specified limits. A type 3AG is recommended.

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SECTION VI

TEST AND ALIGNMENT PROCEDURE

It is the purpose of this procedure to assist a qualified technician in the recalibration of the Model 214 Phase Angle Voltmeter. Under normal circumstances, this instrument, due to the use of solid-state circuitry, should require a minimum of service and recalibration.

The Test Procedure portion of Section VI may be used for incoming acceptance test or for periodic calibration checks. It is recommended that the initial periodic check be made every 3 months and future checks be expanded to 5 months or yearly checks.

The Alignment Procedure portion of Section VI may be used for recalibration in the event there is a failure which requires the replacement of any module or component in the instrument.

Equipment Required

1. Variable Voltage Source

   Frequency Accuracy: ±5%

   Frequency Range: 10Hz to 100Hz

   (e.g., Elin AD0102)

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2. Scale Voltmeter, Monitor

   Accuracy: ± .5% calibrated full scale - 400Hz.

3. Frequency Response Voltmeter, Monitor

   Flat frequency response ± .5%, 10Hz to 100Hz.

   (e.g., Hewlett Packard Model 739AR)*

4. North Atlantic Industries Model RB503 Ratio Box

(* A Hewlett Packard K02-738BR VTVM calibration system may be used in place of the above equipment.)

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I. Preliminary Checks

A. Before turning on equipment, check mechanical zero of the meter and rezero if necessary.

B. Ground Isolation Check (instrument turned off):

1. Check resistance between chassis ground and circuit ground at the signal input terminals. (Link must be removed).

This should read open.

C. Noise Check (instrument on, chassis connected to house ground, ground link in place):

1. Short signal input terminals, apply a 100V reference signal and set reference to red line.

2. Reading on the meter should not exceed 15uv on any range in the TOTAL and FUND Modes. In the Phase Sensitive Modes, the meter indication should be less than 2uv.

II. Voltage Check - Connect instrument as shown in Figure 6.1a

A. Set controls as follows:

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Frequency Switch - Any operating frequency.

Function Switch - Total

Trans/Direct Switch - Direct (Model C only).

B. Apply a voltage to the signal input terminals corresponding to the full scale indication at each position of the Range Switch. The accuracy of the input voltage should be ±0.5%. The 214 should indicate these values ± 2% of full scale.

1. Set Range Switch to 300uv,
2. Apply a 300uv ± .5%, 400Hz to the input terminals.
3. Meter should now read 300uv ± 2%.
4. Set Range Switch to 1mv.
5. Apply a 1mv ±.5%, 400Hz to the input terminals.
6. Meter should now read 1mv ± 2%.
7. Set Range Switch to 3mv.
8. Apply a 3mv ± .5%, 400Hz to the input terminals.
9. Meter should now read 3mv ± 2%.
10. Set Range Switch to 10mv.
11. Apply a 10mv ± .5% , 400Hz to the input terminals.
12. Meter should now read 10mv ± 2%.

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13. Set Range Switch to 30mv.

14. Apply a 30mv ± .5%, 400Hz to the input terminals.

15. Meter should now read 30mv ± 2%.

16. Set Range Switch to 100mv.

17. Apply a 100mv ± .5%, 400Hz to theinput terminals.

18. Meter should now read 100mv ± 2%.

19. Set Range Switch to 300mv.

20. Apply a 300mv ±.5%, 400Hz to the input terminals.

21. Meter should now read 300mv ± 2%.

22. Set Range Switch to 1V.

23. Apply a 1V ±.5%, 400Hz to the input terminals.

24. Meter should now read 1V ± 2%.

25. Set Range Switch to 3V.

26. Apply a 3V, ±.5%, 400Hz to the input terminals.

27. Meter should now read 3V ± 2%.

28. Set Range Switch to 30V.

29. Apply a 30V ± .5%, 400Hz to the input terminals.

20. Meter should now read 30V ± 2%.

21. Set Range Switch to 100V ±2%.

22. Apply a 100V ±.5%, 400Hz to the input terminals.

23. Meter should now read 100V ± 2%.

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24. Set Range Switch to 300V.

25. Apply a 300V ± .5%, 400Hz to the input terminals.

26. Meter should now read 300V ± 2%.

C. Switch the Function Switch to FUND and repeat B (Signal input must be at the frequency indicated by the Frequency Switch).

D. (Model C instruments only)

Switch the Transformer/Direct Switch to TRANS. With Function Switch in FUND position and a signal at the frequency indicated by the Frequency Switch, repeat Step B.

E. Linearity Check

Set the Frequency Switch to any convenient frequency and inject a full scale signal into the signal input terminals.

Switch the Function Switch to FUND.

Change input signal down scale in discrete steps.

Meter should indicate corresponding levels as follows:

Range	Input	Meter X Full Scale
1V	1V	1
1V	.8V	.8
1V	.6V	.6
1V	.4V	.4
1V	.2V	.2
1V	.1V	.1

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III. Frequency Response (Total Mode, Direct only in Model C)

A. Set Frequency Switch to any frequency.

Set Function Switch to TOTAL.

Set Range Switch to 0.1V

Set Trans/Direct Switch to DIRECT (Model C only).

B. Using a wide band oscillator, inject a signal equal to .09V at 400Hz. Monitor this input voltage with a meter which has a known frequency response which is flat to within 0.5% over a range of 10Hz to 100Hz.

C. Sweep the input signal from 10Hz to 100Hz. Meter should indicate .09V ± 2% over this range.

D. Switch Range Switch to 1.0V. Reset input level to .9V at 400Hz and repeat Step C. Meter should indicate .9V ±2% over the frequency range.

IV. Phase Check

The following checks should be made at all active channel frequencies:

A. Set Frequency Switch to desired frequency.

B. Using a 10V voltage level into the reference input terminals,

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set Function Switch to REF ADJ position and HI-LO Switch to LO. Adjust variable ref. adj. control to cause the meter to read "red line" (red mark at half scale on meter).

C. Set Function Switch to 90°.

Set Phase Dial to 0°

Set Range Switch to .001V.

D. Inject a .010V (10 x overload) 0° signal into the signal input terminals.

D. Adjust Phase Dial to cause the meter to read a null (0). The indicated angle should be ± 1° of the input angle. (i.e., with a 0° input, the Phase Dial should read between -1° and +1° which is ± 2 divisions).

F. Repeat D and E in 10° increments to 90°. The Phase Dial readings should all be within ± 1° of the input signal angle.

V. Overload Check

A. Set Frequency Switch to any convenient frequency.

B. Inject a reference signal at the frequency of operation and adjust the ref. level as in IV-B.

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C. Set the Function Switch to 90°.

Set the Range Switch to .1V.

D. Inject a 0° signal into the signal input terminals, at approximately 1V level (10 x overload). Meter will indicate zero.

E. Gradually increase the input signal until overload light comes on. This should occur at approximately 11 x overload (1.1V).

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ALIGNMENT PROCEDURE

I. Preliminary Checks

A. Before turning on equipment, check mechanical zero of the meter and rezero if necessary.

B. Ground Isolation Check:

1. Check resistance between chassis ground and circuit ground at the signal input terminals (link must be removed). This should read open.(Greater than 200 meg-ohms)

C. Power Supply Check:

1. Check Pins C. D, and P of J6.

Each should read +30V ± 1.5V.

2. Check ripple with Hewlett-Packard voltmeter.

Should not exceed the following:

Pin C	7mv RMS
Pin D	7mv RMS
Pin P	85mv RMS

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D. Noise Check:

1. Short signal input terminals, apply a 100V reference signal.
2. Reading on the meter should not exceed 15uv on any range in the TOTAL and FUND Modes. In the Phase Sensitive Modes, the meter indication should be less than 2uv.

II. Voltage Alignment - Connect as in Figure 6.1a

The following adjustments are for the purposes of calibrating the basic voltage gain of the instrument, plus setting the transfer of the filters in the additional channels. It also incorporates the "broadband" adjustment of the 1000:1 input attenuator and the Total Mode frequency response trim.

A. FUND Adjustment

1. Set Range Switch to 0.1V, Function Switch to FUND, and Frequency Switch to "Channel A."
2. Apply 0.1V at Channel A frequency to the signal input terminals.

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3. Adjust R11 FUND Adj. Pot for full scale indication on the meter.

4. Set the Frequency Switch to Channel "B", "C", and "D" and apply 0.1V at each frequency in turn. Adjust R7-B, C, and D for each respective channel to cause a full scale indication on the meter in each case.

B. TOTAL Adjustment

1. Rotate Function Switch to TOTAL position and Frequency Switch to Channel "A". Apply 0.1V at 400Hz and adjust R1 for a full scale reading on the meter.

C. Ref HI-LO Adjustment

The following procedures are for aligning the high level reference attenuator. This attenuator must operate over the entire frequency range of the instrument. It must, therefore, be adjusted for a "flat" amplitude characteristic. and minimum phase shift over the entire frequency range. It may be adjusted by two different methods as follows:

1. For instruments which include frequencies between 160Hz and 1KHz.

a. Set the Frequency Switch to a frequency between 160Hz

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and 1KHz (closes to 400Hz) (Trans/Direct Switch to DIRECT in Model "C" instruments).

Remove 100 Volts from Ref.

b. Set the Reference HI-LO Switch to LO and the variable Ref. Adj. control to minimum (CCW).

c. Apply ~~the~~ same signal to the signal input terminals of Ref. with the Range Switch in the 0 ~~3~~ 3V position (approx. 10 x overload) or 3.0V position in Model "B" and "C" instruments (approx. 5 x overload).

d. Set the Function Switch to the Ref. Adj. position. Apply ~~a voltage~~ to the reference input terminals. Adjust this reference ~~input voltage~~ Ref to cause the meter to read at "red line", (half scale) on the meter (approximately 2.5 to 3V in "A" units and 15V in "B" and "C" units).

e. Set the Function Switch to the 90° position and rotate the Phase Dial until the meter reads zero. (The signal and reference channels have now been adjusted arbitrarily so that zero phase shift exists between them).

Leave phase dial in position found as above,

f. With the Function Switch in the REF ADJ. position, set the Ref HI-LO Switch to the HI position and ~~apply~~ 100V to the ref. channel only and rotate the variable Ref. Adj. control to cause the meter to read "red line" (half scale).

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g. Set the Function Switch to 90° position and adjust C6 (3-12uuf trimmer capacitor) to cause a zero reading on the meter. (Capacitor C6 is located behind the frontpanel near the reference input terminals. It may be reached easily be removing the instrument's top cover).

h. Repeat Steps a through g at all phase sensitive operating frequencies. Do not readjust C6. This is to check performance of the attenuator. If any errors exceed ±.25°, a malfunction is indicated.

2. For instruments which do not include frequencies between 160Hz and 1KHz.

a. Set the Ref HI-LO Switch to HI and the Function Switch to the Ref. Adj. position.

b. Apply a 100Hz signal tothe Ref. input terminals.

c. Adjust the variable ref. control to cause the instrument to read full scale.

d. Using a meter with a frequency response which is flat within ±.5% from 100Hz to 10KHz, monitor the input voltage. (For Model "B" and "C" instruments the voltage must be monitored at terminals H and

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J of T4).

e. Reset the input signal to 10KHz and readjust the level to precisely the same voltage applied at 100Hz (as monitored in d above).

f. Adjust C6 to cause the 214 meter to read full scale. The reference attenuator is now "broadbanded" and will have minimal phase shift.

D. 1000:1 Input Attenuator Adjustment

The 1000:1 input attenuator requires an adjustment which is similar to the one just made in C above. This attenuator is used not only for phase sensitive operation but also for TOTAL Mode and therefore will operate over an even wider range of frequencies. Two difference methods may also be used to adjust this attenuator.

1. For instruments which include frequencies between 160Hz and ~~10KHz~~ 1KHz (Connect instruments as shown in Figure 6.1a)

~~a. Set voltage source for precisely 10V output as measured on the Monitor Voltmeter at a frequency corresponding to 214 frequency closest to 600Hz.~~ (400Hz)

~~b. Set Ratio Box to .01V (.001000).~~

c. Set Ref. HI-LO Switch to HI and Function Switch to Ref. Adj. Apply 100V (400~) to ref. input. Adjust variable Ref. Control for "red line". Set range switch to .01V and apply .01 volts.

d. Set Range Switch to .001V, Function Switch to 90°, Frequency Switch to above-mentioned frequency, 400~ Trans/Direct Switch to ~~DIRECT~~ TRANS.

e. Rotate Phase Dial until meter reads precisely zero.

f. Set Range Switch to 10V position and Function Switch to FUND.

g. Set Ratio Box for 10V (1.00000).

h. Adjust R106 for full scale reading on 214 meter. 1K (R106 is located on the Range Switch).

i. Set Function Switch to 90° and Range Switch to 1V (10 x overload).

j. Adjust C101 for zero reading on 214 meter (C101 is located on the Range Switch).

k. Repeat Steps f through j until best results are obtained. This is required due to the interaction of the two controls.

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2. For instruments which do not include frequencies between 160KHz and 1KHz

a. Set the Range Switch to the 1V position, the Function Switch to TOTAL, the Frequency Switch to any frequency position. (In Model C instruments, Direct/Transformer Switch to DIRECT.)

b. Apply a 1V ± .5%, 100Hz signal to input terminals, monitor with meter which has a frequency response flat within ± 1%.

c. Adjust R105 for full scale reading on the 214 meter.

d. Reset the signal input to 10KHz, 1V ± .5%.

e. Adjust C101 for a full scale reading on the 214 meter.

f. Recheck Steps B through C, readjusting as necessary. The 1000:1 input attenuator is now "broadbanded" and will have minimal phase shift.

D. Frequency Response Trim (Total Mode)

The frequency response of the 214 in the TOTAL Mode should not require retrimming unless an amplifier is replaced.

Note that in Model C instruments, in the TRANS IN position, the frequency response is limited to that of the transformer.

1. Set the Function Switch to TOTAL, the Frequency Switch to any frequency position, theRange to .01V, and in Model C instruments, set the Direct/Transformer Switch to DIRECT.
2. Using the wide band voltage source, inject a .009 volts signal (90% of full scale) at 400Hz.
3. Check this reading at 100KHz.
4. If the error observed exceeds ± 2% of full scale of the initial reading, it may be corrected by selecting a new value for C10.

III. Phase Alignment

This alignment will adjust the instrument for zero phase shift between the signal and reference channels.

A. Connect the 214 as shown in Figure 6.1b. This will require a precise 90° phase shifted signal which may be generated as indicated in this figure.

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B. Set Frequency Switch to the frequency to be calibrated. 400~

C. Set Function Switch to REF ADJ, inject 100V at the frequency of operation into the reference input terminals. Adjust reference controls for "red line" on the meter.

Feed approx. 100V into phase shifter [illegible] for 0 and 180 scale reading on VTVM

D. Set the Function Switch to 0°, Phase Dial to 0°, and ~~Range Switch to .01V.~~

E. ~~Connect the precise 90°, .01V signal to the signal input terminals.~~

F. Set Range Switch to .001V (10 x overload) and adjust R23-A, B, C, or D as the case may be to cause the meter to read 0.

G. Set Function Switch to 90° and Phase Dial to 90°.

H. If an error exists, readjust R23-A, B, C, or D to divide the error between Steps 6 and 7.

Perform final quick check.

IV. Phase Dial alignment on Phase Shifter Pot. R8.

The following is a procedure for mechanically aligning the Phase Dial on the shaft of the phase shifter pot (R8). This is necessary in the event that a Phase Dial, a phase pot, or both are disassembled or replaced. The 0° and 90° points on

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screw. Reconnect ohmmeter to CW tap point and [illegible] Phase Dial until wiper of R8 is on CW tap point. Dial should now read zero degrees. If not, reposition dial so as to achieve the best compromise reading between the two taps. For example, if the zero degree point reads low, the 90° point should read high by the same amount. Fully tighten knob set screw and recheck to make sure dial has not slipped during tightening.

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the dial must be aligned to coincide with the taps (terminals 4 and 5) of the pot.

[illegible] high impedance ohmmeter (i.e.,

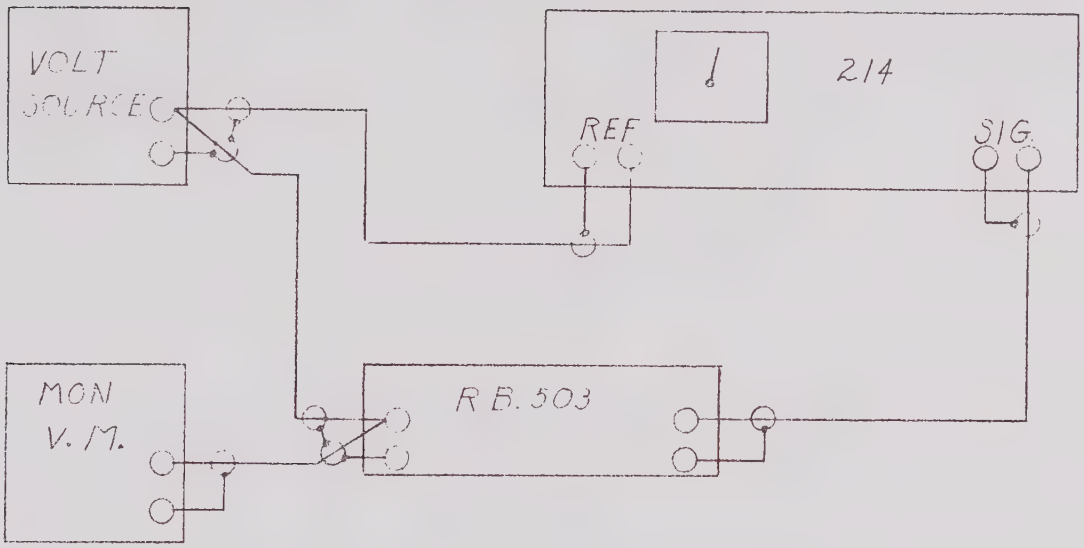


Figure 6.1A

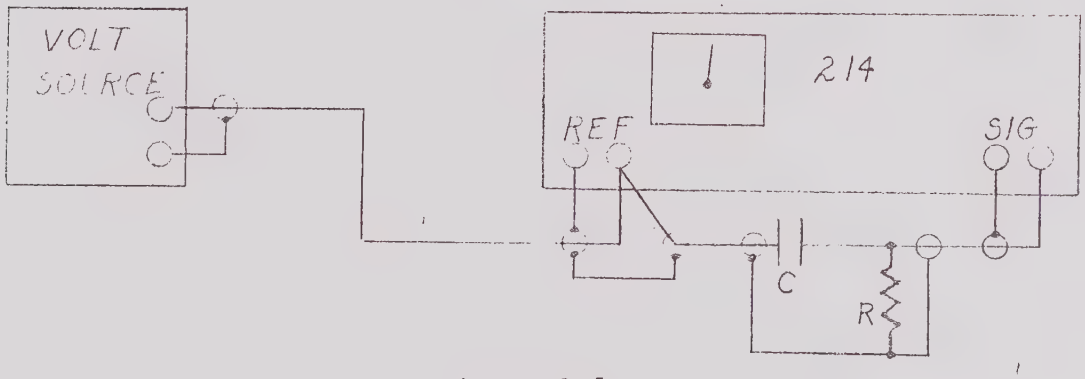


Figure 6.1B

400Hz
C = 500pf
R = 80 ohms

For other frequencies
X_C approx. 10000 times R
R less than 200 ohms

TEST CONNECTIONS

CAUTION

High voltage exists at several points in the instrument. Normal precautions consistent with good practice should be taken to reduce shock hazard.

A potential shock hazard exists when ungrounded power source or ungrounded case operation is employed. Persons operating the instrument should be made aware of and take precautions against this condition.

North Atlantic Industries, Inc. cannot be held responsible for damage to person or property in the process of or as a result of maintenance, calibration, or setting up of the instrument.

WARRANTY

North Atlantic Industries, Inc. warrants its products against defects in material and workmanship for one year from the date of the original shipment. Our liability is limited to repairing or replacing products (except fuses and electron tubes) which prove to be defective during the warranty period.

North Atlantic Industries, Inc. is not liable for consequential damages or for any damage or injury to persons or property resulting from the operation or application of any of its equipment.

Warranty is voided if there is evidence that the product has been operated beyond its design range, improperly maintained, or physically mistreated.

In the event of a malfunction in a product under warranty, the purchaser should notify his local Sales Representative or the Sales Department of North Atlantic Industries, Inc. giving full details of the defect and providing the model and serial number of the instrument. Service data or shipping instructions will be forwarded promptly. There is no charge for warranty repair of products, except transportation charges.

North Atlantic Industries, Inc. reserves the right to make changes and improvements in its products without any liability for incorporating such changes or improvements in any products previously sold.

No other warranty expressed or implied is offered other than the foregoing.

Estimates of charges for out of warranty repairs or other service work will be supplied before work begins. Out of warranty repairs will only be made following the receipt of purchaser's authorization of applicable charges.

Claims for Damage in Shipment

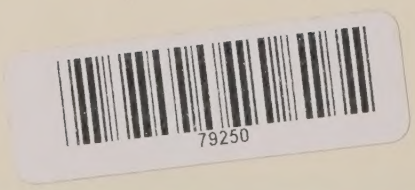
The purchaser should inspect and functionally test the product in accordance with the instruction manual as soon as it is received. If the product is damaged in any way, including concealed damage, a claim should be filed immediately with the carrier, or, if insured separately, with the purchaser's insurance company.

(turn over for Shipping Instructions)

NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. OVerbrook 1-8600

Shipping

On products to be returned under warranty, await receipt of shipping instructions, then forward the instrument prepaid to the destination indicated. The original shipping containers with their appropriate blocking and isolating material is the preferred method of packaging. Any other suitably strong container may be used providing the product is wrapped in heavy paper or a plastic bag and surrounded with at least four inches of shock absorbing material to cushion firmly, preventing movement inside the container.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